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Semantic segmentation of rock images and ensemble approach for deep learning methods

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The segmentation of images obtained from different imaging techniques, such as X-ray computed microtomography (μCT) and scanning electron microscopy (SEM), is a critical step towards quantitatively describing various features of geomaterials. In this work we evaluate the capability of convolution neural networks (CNNs) to segment both μCT and focused ion beam-SEM (FIB-SEM) images. The performance of five different 2D CNN architectures (U-Net, Attention U-Net, VGG16, ResNet, and MultiResUnet) as well as a 3D CNN architecture (U-Net) is assessed on four independent datasets including sandstone, carbonate chalks, and shale. Each of these datasets is composed of three-dimensional image stacks and corresponding ground truth segmentation labels obtained using various traditional image processing techniques. Our results indicate that deep learning architectures can successfully be applied to the task of semantic segmentation for μCT and FIB-SEM images with frequency weighted accuracy between 94% and 99% and can perform better than manual segmentation to recover the natural morphology of original images. We also find that ensemble solutions with multiple trained models obtained from single training process consistently improve prediction accuracy in comparison to single-model (i.e., the best model in the single training) approaches across multiple datasets. In addition, our results indicate that transfer learning can allow for models to converge more quickly during training and that generic image features (learned from a large dataset such as ImageNet) can be applied to improve model performance in some cases. A comparison in performance among different CNN architectures highlights the connection from classification outcomes to underlying features of each architecture and its hyperparameters. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

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Participation

Online

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