Grain Segmentation and Region Mask Generation in Digital Rock Images Using Convolutional Neural Networks

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Abstract

Digital imaging and image-based analysis of rock samples are becoming a routine part of reservoir characterization and core analysis. Rock samples at various resolutions and sizes are imaged using lab-based imaging systems such as X-ray CT scanners, and scanning-electron and optical microscopes. These images are then used to qualitatively and quantitatively estimate rock properties and assess reservoir quality [1]. With the advances in imaging hardware, and image visualization and analysis software, one can now visualize and calculate rock properties such as porosity, grain-size distribution, and grain morphology at resolutions varying from 100s of microns to 10s of nanometers. One main challenge in analyzing these rock images is segmenting and separating individual grains that form the rock structure. The result of this step affects the quality of subsequent steps of grain size and shape analysis. This process has a big influence on digital grain models and thus on simulating mechanical properties. The current methods of segmenting and separating grains rely on segmentation algorithms which rely on gradients or edges such as watershed algorithms. In the case of samples with severe diagenesis or multi-scale grain sizes the results are not accurate. We propose a new method for grain separation using convolutional neural networks. This model is trained on a database of rock models generated using a 3D process-based modeling technique. Convolutional Neural Network (CNN) models have shown to be more successful over traditional machine learning methods. Our proposed system uses Mask R-CNN [2], a network designed to work with and generate accurate region maps. Our proposed Mask R-CNN

model will be trained on complex geometry while assigning each geologically significant morphology to different classes. In the grain-separation problem, generating ground-truth data by manually marking the grain-boundaries and separation lines on the rock images can be a tedious and time-consuming process. We use a 3D process-based rock modeling technique to model the formation of rocks by simulating sedimentation, compaction, and diagenesis of the grains [3]. As this process is generative, individual grains and their labels can be maintained, which can be used in the training process. The CNN model is used to make predictions on real images of rocks acquired in the lab and generate individual labels. The results of this analysis are compared against grain-size distributions obtained through other techniques.

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