Unsupervised Segmentation of Rock MicroCT Scans Using Deep Learning

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Abstract

Micro-CT imaging is an effective technique to visualize the three dimensional microstructures of the main rock constituents, such as grains and pores. The traditional workflow of Digital Rock Physics (DRP) includes image processing, segmentation and finally, the numerical simulations to estimate the properties of the rock sample. Because the segmentation step impacts the simulation results, one of the goals of this process is to accurately segment the pore and mineral phase in an automatic, efficient and standardized way. Too much human interference in this process could add significant bias to the results in addition to being a costly process. Deep Neural Networks (DNN) have been extensively used to solve problems in various areas of knowledge. A particularly useful class of DNNs when working with images are the Convolutional Neural Networks (CNN), usually employed in conjunction with supervised training, which needs labeled data for training. Recent advances have proposed new unsupervised and semi-supervised training algorithms for segmenting photographs with breakthroughs in such tasks. In this work, we apply a state-of-the-art unsupervised segmentation algorithm to a micro-CT benchmark image, the Berea sandstone. We evaluate its accuracy comparing to a baseline available in the literature. The original unsupervised CNN has been modified to use a cubic 3D convolutional window instead of a 2D one. This modification allows for the analysis of the full 3D shape and features of the grains and pores present at the rock sample, improving the segmentation quality considerably, compared to the 2D version. The only a priori assumption provided about the image is the number of classes to be found (the pore and different mineral phases). We also run the same algorithm in a semi-supervised fashion, useful when access to a labeled or partially labeled dataset is available. One can also produce

labels of a small section of the scan to be used as training inputs for the semi-supervised case. Preliminary results reveals a promising technique for a semi automatic and interactive segmentation methodology. The produced segmentations were able to separate the two main mineral phases present at the Berea sandstone as well the pore space from the grains when evaluated qualitatively. Moreover, the 3D adaptation showed significant improvement over the 2D results at the cost of a much higher memory and processing requirements. Future improvements include the use of an interactive and iterative procedure, where the expert could segment first the pore space from the grains by partial labeling and repeat the process for separating the mineral phases inside the grain space.

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