Applications of end-to-end deep learning models in processing digital rock data

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Summary

Augmented Intelligence (AI) and Deep Learning (DL) techniques and the production of digital rock data have become powerful tools for studying and characterizing reservoir rocks properties—such as pore structure—at unprecedented resolutions. The rise of powerful imaging methods (e.g. micro-CT scanner) has enabled acquiring a substantial amount of image data of different rock properties under varying conditions. The caveats of digital rock data analysis techniques are the resolution and processing of these types of data. Image enhancement and segmentation are often time-consuming and subjective to the methods used. Deep learning as an emerging new means of image processing offers a great potential for automating image analysis tasks that can significantly speed up characterization. The research presented here demonstrates the use of deep-learning models for seamless processing of scanning electron microscopy (SEM) or micro-CT images of rock samples. Image denoising, resolution enhancement, semantic segmentation, and prediction of several properties such as porosity are shown to be successfully performed by these models. The automation of these tasks greatly reduces the time spent on each step. Additionally, as more data become available better models can be trained to push the boundaries of data characterization past physical limitations of currently available imaging devices.

We show through the use of several connected convolutional neural networks (CNN) that images acquired using SEM or micro-CT data can be directly characterized right out of the instrument using trained CNNs. In our work, a network first denoises the image, a second network takes the output of the denoiser and enhances the resolution by a factor of 4. The third network segments the super-resolved images. A final network is also attached to quickly obtain information about the pore size and porosity of the samples. The use of these models greatly reduces processing time. Additionally, it offers flexibility in terms of obtaining large lower resolution images and boosting their resolution through deep-learning models.

The novelty of this work is in the use of several state-of-the-art CNN models simultaneously to pre-process and produce quick results using raw microscopic rock images. We believe the industry, as well as the researcher, can benefit substantially by adopting these new tools in their analysis that can save time and enhance the workflow.

Method / Workflow

For demonstration purposes, we use publicly available sandstone micro-CT images (Neumann et al. 2020). The workflow is schematically shown in Figure 1. The input to the model is a low-resolution noisy image. The first CNN model denoises the images using UinUNet network architecture (Yu et al. 2019). The output of this network is a clean but low-resolution image. A second network then super-resolves this low-resolution image to 4x its resolution using an Enhanced Deep Residual Networks architecture (EDSR) (Lim et al. 2017). The super-resolved image is then fed into a UNet model for segmentation. The final network uses CNN and fully connected layers at the end to predict several attributes such as porosity and pore size.

Our results show that image denoising, super-resolution, semantic segmentation and characterization all can be done seamlessly using the appropriate deep-learning models. The use of these models greatly reduces processing time and costs.

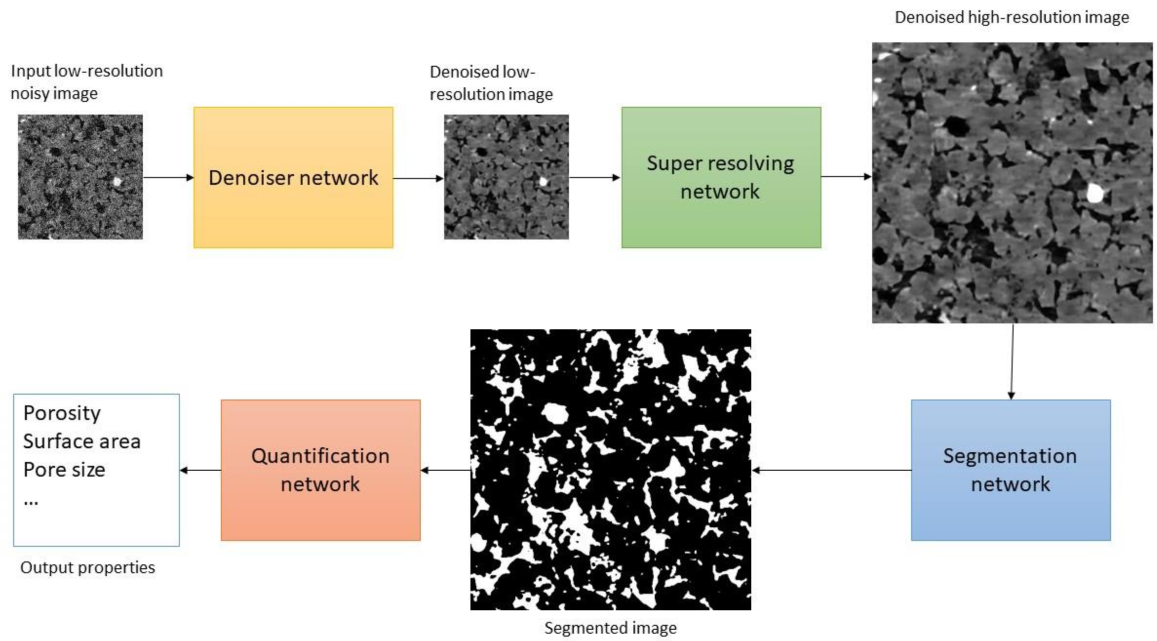

Figure 1 Schematic representation of the workflow of the connected CNNs

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