Contribution ID: **434** Type: **Oral Presentation**

3D Pore Segmentation and Pore-Scale Simulation by Deep Learning

Tuesday, 14 May 2024 12:30 (15 minutes)

Objectives
This study aims to optimize the characterization and prediction of permeability and relative permeability in porous media through a multi-faceted approach. The primary objectives include achieving accurate 3D reconstruction of rock core images, implementing advanced deep learning models for segmentation, and addressing computational challenges associated with the Lattice Boltzmann Method (LBM) for permeability calculations. Furthermore, the goal is to enhance scalability by training models on relatively small representative elementary volumes (REVs).
Methodology
In this work, we perform the data acquisition of rock core images through CT scanning, followed by the 3D reconstruction of multiple 2D slices. We develop deep learning-based segmentation models to enhance pore segmentation, including 3D UNet, Attention-3D UNet, and 3D UNet-transformer. To resolve the computational bottleneck of LBM for large REV, we develop 3D-CNN models to take 3D segmented pore images offered by the segmentation network as input and learn to predict labels of permeability and relative permeability curves generated by LBM solver at relatively small REVs. Once trained, these 3D-CNN models can predict rock properties on a larger REV without computational limitations.
Results
The 3D reconstruction using the 2D slices yields highly accurate representations of rock core images. Subsequent segmentation employing 3D UNet, Attention-3D UNet, and 3D UNet-transformer identify the most accurate and effective porous network, providing valuable insights into the rock structure. The segmentation model achieves scalability by efficiently predicting permeability for larger REVs by addressing the computational challenges associated with LBM. The permeability and relative permeability values determined through up-scaled predictions of the trained model closely align with LBM data, affirming the reliability and utility of the integrated approach. This research contributes a comprehensive and efficient workflow for permeability prediction in porous media, combining advanced imaging, deep learning segmentation, and permeability prediction.
Additive Information
The deep learning-based workflow developed in this work can efficiently solve the scalability limitation of physics-based solvers, such as the Lattice Boltzmann Method, as it can accelerate the computation and extend to predicting permeability in larger REVs, which is about scalability. This dual advantage of efficiency and scalability represents a notable breakthrough, highlighting the efficiency and effectiveness of our methodology in overcoming the limitations occurring in digital rock.

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References

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Session Classification: MS15

Track Classification: (MS15) Machine Learning and Big Data in Porous Media