Contribution ID: **21** Type: **Oral Presentation**

Promises, Challenges and Prospects of Deep Learning for Providing Insight into Multi-phase Flow Through Porous Media

Monday, May 31, 2021 9:40 AM (15 minutes)

The advent of deep learning marked a milestone in the real-life applicability of machine learning tools, as now very complex problems can be solved with unprecedented accuracy. Deep neural networks generally require little explicit prior knowledge and are distinctively efficient in extracting complicated patterns. These capabilities turn them into feasible candidates for replacing and/or assisting conventional time-consuming and computationally-expensive methods involved in pore-scale modelling, such as reconstruction, segmentation and single-/multi-phase simulations.

This work aims to show how the power of deep learning can be harnessed to both estimate porous-media properties and develop new insights. Our main objectives are: (1) provide a general overview of how deep neural networks have already been used in terms of single/multi-phase flow characterization; (2) demonstrate the potentials of deep learning in digital rock physics through case studies; (3) discuss deep-learning-based approaches to explore the physics of the porous media.

First, the relevant body of research is considered so that advancements, gaps and potentials can be identified. Then, an implementation map is laid out, encompassing the simplest to most comprehensive applications. Inputs can range from grey-level images to customized feature maps, while targets can span from static properties to complex, dynamic multi-phase properties (e.g., resistivity index and fluid distribution). Secondly, case studies are presented where porosity, permeability and relative permeability are predicted from micro-CT (e.g., synchrotron beamline) images and rock-fluid characteristics. A great challenge is to achieve the simulations at representative sample image sizes, which makes hyperparameter sweeping extremely taxing for the researcher and demanding on the hardware.

Thirdly, future research is discussed. It is proposed that to develop reliable multi-phase predictors, large databases must be synthesized by collecting, resampling, augmenting, and grouping images and the corresponding properties. Consequently, deep neural networks can be trained for various rock types (e.g., carbonate) and processes (e.g., two-phase unsteady-state drainage). Singular or ensembles of networks may either be used to make predictions or to serve as the base to be customized for other applications, i.e., transfer learning. Final models can be put to ultimate real-life testing by comparing against experimental data, e.g., phase distributions from synchrotron imaging.

Rather than trying to create mere black-box estimators, one must strive to understand how the networks extract information, by looking at layer architectures, weights and other elements. The goal should be to gain insights into various flow functions (e.g., uncover the link between macroscopic properties and pore morphology and/or wettability) and the physics of certain flow behaviours (e.g., snap-off). This has already been done in such fields as object recognition, for instance, to figure out the level of feature abstraction at different layers. Furthermore, since trained models are very fast to run, they make perfect assets for such tasks as sensitivity/uncertainty analysis and back-calculation of input features, for instance, to see what wettability distribution can result in a specific flow parameter.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

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