Contribution ID: **756** Type: **Poster (+) Presentation**

Application of Convolutional Neural Networks in Flow Simulation of Porous Media: Unsupervised Image Segmentation and Lat-Net for LBM Simulation

Thursday, 3 June 2021 20:00 (1 hour)

Three-dimensional high-resolution images, obtained from X-ray micro-computed tomography (μCT) in a non-destructive and non-invasive manner, can be used in digital rock physics (DRP) studies, including property characterization, hydraulic and mechanical behaviour modelling, flow and transport simulation, etc [1, 2]. In recent years, machine learning received great success in various fields of DRP. This work applied two convolutional neural networks to the Lattice-Boltzmann flow simulation: unsupervised image segmentation and Lat-Net for LBM simulation. These two networks can improve the accuracy and efficiency of image segmentation and accelerate the single flow simulation without sacrificing little accuracy. The data is the X-ray μCT image of a sandstone sample, which is first saturated with water, then replaced by supercritical CO2.
As a crucial step of standard DRP workflow, image segmentation has a profound impact on the accuracy of follow-up analysis and modelling processes. Recently, supervised learning algorithms for image segmentation have been developed greatly. However, the keystone of those methods is the high-quality label images, which are not always accessible or computationally expensive, and time-consuming to obtain [3]. Nowadays, unsupervised learning algorithms for image segmentation are still under exploration and the design of model architecture is very challenging. W. Kim and A. Kanezaki proposed a brand new convolutional network, following the criteria of image segmentation: '(a) pixels of similar features are desired to be assigned the same label, (b) spatially continuous pixels are desired to be assigned the same label, and (c) the number of unique labels is desired to be large.'[4] This model can optimize the pixel labels based on the representations and the parameters are updated via gradient descent. With the advantage of the convolutional operator to analyze the shape and the pattern of the target, this method showed high accuracy to segment the raw images into three phases: pore space (including water and supercritical CO2) and rock grain, in a very short processing time (several minutes per image).
After the image processing and segmentation, apply the Lat-Net [5] to complement the Lattice-Boltzmann method simulation. LBM can be constructed to operate based on the minimum assumptions and modelling the complex materials without geometric simplification [6]. Correspondingly, LBM simulations are extremely computationally and memory demanding. The Lat-Net uses the similarity between LBM simulation and convolutional neural network: for the D2Q9 case, consider the streaming operator as a 3 by 3 convolution and collision step as 1 by 1 convolution. Then, Lat-Net can compress the state size of a simulation and learn the dynamics of this compressed form by using convolutional autoencoders and residual connections in a fully differentiable scheme. After some time step, the steady-state velocity map and permeability resulting from Lat-Net would be compared with the LBPM software package (J. E. McClure) [6], which is a well-developed LBM software.

Time Block Preference

Time Block C (18:00-21:00 CET)

References

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