Answers to Q&A, Interpore webinar, Jan 10, 2023

- **Could you comment about the correlation of Kozeny-Carman, How can we correlated an scalar with a tensor?** (16:12:32 From Camacho Rodolfo)

Kozeny-Carman relationship is derived for the case of a sphere packing of equal spheres. In that case, directionality does not matter and the tensorial property reduces to a scalar. The derivation is available in [1], I trust in the petrophysics chapter.

If one has a velocity field, i.e. a full vector field in 3D, as is the case in simulation, then one can integrate that field to get tensor or a scalar, depending on the assumptions made.

- **Is there a fee for data storage on DRP?** (16:17:50 From Amin Sadeghi)
  There is a fee for storing larger datasets, similar to open science journal fee. It is unfortunate, but the financial burden of supporting the portal is real as it requires professional computer science support, as opposed to maintaining a single piece of software. https://www.digitalrocksportal.org/user-agreement/
- **Could you tell us how to share our data in the portal?** (16:20:09 From DEBORA SANDRA VEGA RUIZ)
  Your register/create an account, https://www.digitalrocksportal.org/accounts/signup/ and after that, when you login, click to create a new project. You are guided from that point.
- **What is the image size (AdWR, 2020)?** (16:20:52 From Amin Sadeghi)
  In that work, the image sizes were up to 1000 cubed, but during processing, they were cut into 80 cubed. That is also a disadvantage of the method, as presented, and was fixed in the follow up work, Santos et al. 2021.
- **How many hours you need to train a CNN?** (16:21:01 From Peng Haonan). A single pass can be done on the order of a few days, however, in the initial stages when developing the method, there is a lot of trial and error.
- **Maybe quantum computing of images of porous media in future! Would help you not only to open it but also to analyze it, that would not take much of time hopefully:** https://link.springer.com/article/10.1007/s11242-022-01855-8 (16:21:52 From E. Nikooee)
  Agreed, though I cannot speak much to this at this time as I have not tried it myself. There is a session about it I am hoping to attend at the 17th U. S. National Congress on Computational Mechanics will be held from July 23 to 27, 2023, in Albuquerque, New Mexico, namely 'Advancements in Machine Learning Techniques and Quantum Computing for Geoscience and Climate Modeling Applications,' (https://17.usnccm.org/congressMS)
- **How your calculation method would work for nanopores?** (16:22:26 From Dr. Margarita Russina)
  It would work assuming that the nanopores are connected. That is a non-trivial assumption, however, as the FIBSEM images of shale nanoporosity often show a disconnected pore space (in addition to being expensive to image and heavily guarded). Further, FIBSEM has very small field of view (a few micrometers on a linear side) and is thus not representative. We have worked on reconstructing representative volumes from large areal images (BIBSEM),

[2–4], alas that is a whole another talk, and AI can help in that realm, but the workflow is more involved.

- **In image classification, one of the advantages of using deep CNNs was that they no longer required manual feature engineering. What do you think can be done to do the same in petrophysics?** (16:33:37 From Amin Sadeghi)
  Predicting a flow field based on the image is way more complicated than figuring out what is pore or solid in an image (segmentation problem), it's adding a very, very nonlinear problem (Navier-Stokes equation) on top. Consequently, avoiding manual feature engineering is that much more difficult.
- **If we have measured perm data from core plugs and use it for training, does this CNN approach potentially scalable for core plug sizes?** (16:46:26 From Billal Aslam)
  Yes, potentially it is, but it is a problem on multiple scales and assumes having images from pore scale to core scale. Doable in some near future, but with more to constrain and train.
- **How did you incorporate the structure representation of the heterogeneity in the NN model?** (16:46:52 From Arsalan Zolfaghari, Thermo Fisher Scientific)
  By using NN model on four different length scales in the same image. Please refer to [5].
- **What about to conduct a yearly match (definitely with prize :)) for students by Interpore (like the old SPE match) to increase the accuracy of ML predictions on defined datasets (from DigitalRockPortals)** (16:49:11 From Saeid Sadeghnejad)
  That's a great idea!
- **How much time it takes whole process of simulation permeability in a core plug (1 inch diameter) including the training?** (16:52:26 From DEBORA SANDRA VEGA RUIZ)
  In this workflow we use high resolution images that are often 1000 x 1000 x 1000 numerical cells, and approximately 4-5 micron (for a sandstone) in linear length of a cell. There are codes that can handle larger images, up to 5000 cells on a side, see [6]. This is typical size in simulation (takes on the order of hours), or ML prediction (a matter of seconds if a trained CNN exists). So, that is a volume of approx. 5 milimeter on a side and is assumed representative of the plug. Another option is to sample along the plug in different locations for high resolution imaging.
- **Do you expect the particle deformability to play a large role for particulate flow through the rock samples you studied (currently only rigid particles are considered, right? e.g. proppants)** (16:53:53 From Qi Zhou)
  Yes, but particle deformability is more an issue in soft porous media such as in blood flow. Presently, just combining flow and interaction of the hard particles with each other and the walls is pretty computationally intense [7]. As far as high stress environments in subsurface, it should be possible to exert stresses on a side of a fracture that would deform both the neighboring matrix and the proppant particles, but that would not be a good problem for discrete element

method (DEM) used in the cited work as it assumes spherical particles. Particles could also break, rather than continuously deform, and then we are outside of linear elasticity regime.

- **What was the image size in the slide you showed from AdWR 2020? Thanks!** (16:54:49 From Amin Sadeghi)
  - Answered above.
- **How digital rock portal compares with other long-term sci data storage options?** (16:55:38 From Siarhei)

There is visualization and data about the datasets (termed metadata) that is collected and enables using the data. Most long term storage does not care about collecting that information, but simply stores a folder (or archive for you). We actually curate the images, provide feedback etc.

- **Do you have any idea about transformations for 3D tomography rock images?** (17:00:52 From Nguyen Van Thao)
  Yes, that is a related and separate problem, and a topic for an entire another talk. Please check out review papers [8,9], which are some of many, and for deep learning approaches review, see [10].

References

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