Contribution ID: **511**

Type: **Poster Presentation**

Feature alignment Generative Adversarial Network for Multi-scale fusion reconstruction of Core Images

Thursday, 16 May 2024 10:20 (1h 30m)

The accurate modeling of the three-dimensional structure of porous media is important for the study of the linkage between the microscopic characteristics and the macroscopic physical properties/phenomena. Multi-scale pore structures are widely distributed in nature and industry. However, due to the tradeoff between field of view (FOV) and resolution, it is difficult to obtain high-resolution images with a large field of view in a single imaging process. High-resolution images with small field of view can capture more detailed features, but lack representation of the entire microstructure. Low-resolution structures with a large field of view are more representative, but lack detailed features. Multi-scale fusion reconstruction is an effective way to model large-view and high-resolution structures. Previous studies have shown that the method based on deep learning in particular has great potential in multi-scale reconstruction. In this paper, we propose a feature alignment Generative Adversarial Network (FAGAN) to achieve multi-scale fusion modeling of digital core images, which combines 2D small-FOV high-resolution images (2D HRI) and 3D large-FOV low-resolution images (3D LRI). There are dimensional differences between 2D image features and 3D image features, and 3D feature space can represent 3D spatial structure more accurately. Therefore, the generator of FAGAN uses a two-stream network to extract the semantic features of 3D LRI and 2D HRI respectively. A feature reconstruction module is designed to convert 2D image feature F_{2D} into 3D feature representation $F_{(2D\sim 3D)}$, so as to realize the feature fusion of 2D HRI and 3D LRI in 3D feature space. The semantic consistency of F_{2D} and $F_{(2D\sim 3D)}$ is constrained by combining the feature space alignment loss function (FSAloss). In addition, a feature alignment module is designed to align $F_{(2D\sim 3D)}$ with 3D LRI semantic feature F_{3D} to ensure the correct fusion of features. The visualization results show that the structure generated by the model follows both the spatial geometry of 3D LRI and the fine details of 2D HRI. The validity of the reconstructed results is further verified by the statistical parameters (two-point correlation function, pore diameter distribution, shape factor distribution, etc.) and numerical analysis (permeability, etc.) of the reconstruction structure and the real structure.

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Session Classification: Poster

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