Contribution ID: **574**

Type: **Oral Presentation**

Efficient Surrogate Modeling of Subsurface Flow in Porous Media Using Transfer Learning with Multifidelity Data

Thursday, 16 May 2024 09:35 (15 minutes)

ABSTRACT
In subsurface flow settings, deep-learning-based surrogate modeling is shown to be an effective approach to deal with cases that require a substantial amount of model simulations. However, a large number of high-fidelity training simulations are usually required to construct these deep-learning-based surrogate models. For large-scale models, it can be computationally prohibitive to perform these training simulations. To address this limitation, in this work, we develop a new approach to construct surrogate models using transfer-learning with multifidelity training data. The model is based on a U-Net deep-learning architecture, wherein we introduce a specialized input layer, in order to allow for gradual model fine-tuning with multifidelity data, and an embedded layer that is designed to deal with time-varying source/sink terms. The procedure of building such surrogate models can be divided into three steps. In the first step, a relatively large amount of low-fidelity simulations, generated from upscaled coarse models, are used to build a pre-trained deep-learning model. In the second and third steps, the input, output, encoder, embedded, and decoder layers of the model are progressively fine-tuned, requiring a relatively small number of high-fidelity simulations. In this study, we use 400 low-fidelity and 100 high-fidelity training simulations, which leads to about a 70% reduction in computational cost of the overall procedure. The proposed procedure is applied to three cases with different number and locations of source/sink wells. In all cases, our proposed surrogate models trained using multifidelity data provide predicted dynamic pressure and saturation fields that are in close agreement with the corresponding model trained using only a large number of high-fidelity data. In addition, our introduction of the embedded layers is shown to effectively improve the prediction accuracy of the surrogate model when dealing with time-varying source/sink well terms, in comparison with traditional approaches based on similar network architecture.

Keywords：Subsurface Flow Simulation; Porous Media; Surrogate Model; Transfer Learning; Multifidelity Training Data;

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Session Classification: MS15

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