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A TgCNN-Based Surrogate Model for Subsurface Oil-Water Phase Flow under Multi-Well Conditions

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Abstract : The uncertainty quantification and inversion problems of subsurface oil-water phase flow usually require extensive repeated forward calculations for new runs with changed conditions. To reduce the computational time, various forms of surrogate models have been built. Related research shows that deep learning has emerged as an effective surrogate model, while most surrogate models with deep learning are purely data-driven, which always leads to poor robustness and abnormal results. To guarantee the model more consistent with the physical laws, a coupled theory-guided convolutional neural network (TgCNN) based surrogate model is built to facilitate computation efficiency under the premise of satisfactory accuracy. The model is a convolutional neural network based on multi-well reservoir simulation. The core notion of this proposed method is to bridge two separate blocks on top of an overall network. They underlie the TgCNN model in a coupled form, which reflects the coupling nature of pressure and water saturation in the two-phase flow equation. The model is driven by not only labeled data but also scientific theories, including governing equations, stochastic parameterization, boundary, and initial conditions, well conditions, and expert knowledge. The results show that the TgCNN-based surrogate model exhibits satisfactory accuracy and efficiency in subsurface oil-water phase flow under multi-well conditions.

Keywords : coupled theory-guided convolutional neural network, multi-well conditions, surrogate model, subsurface oil-water phase
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