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Physics-Informed Convolutional Neural Networks for Reservoir Simulation

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Abstract : Despite the significant progress over the last decades in reservoir simulation using numerical discretization, meshing is complex. Moreover, the high degree of freedom of the space-time flow field makes the solution process very time-consuming. Therefore, we present Physics-Informed Convolutional Neural Networks(PICNN) as a hybrid scientific theory and data method for reservoir modeling. Besides labeled data, the model is driven by the scientific theories of the underlying problem, such as governing equations, boundary conditions, and initial conditions. PICNN integrates governing equations and boundary conditions into the network architecture in the form of a customized convolution kernel. The loss function is composed of data matching, initial conditions, and other measurable prior knowledge. By customizing the convolution kernel and minimizing the loss function, the neural network parameters not only fit the data but also honor the governing equation. The PICNN provides a methodology to model and history-match flow and transport problems in porous media. Numerical results demonstrate that the proposed PICNN can provide an accurate physical solution from a limited dataset. We show how this method can be applied in the context of a forward simulation for continuous problems. Furthermore, several complex scenarios are tested, including the existence of data noise, different work schedules, and different good patterns.

Keywords : convolutional neural networks, deep learning, flow and transport in porous media, physics-informed neural networks, reservoir simulation
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