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Anchored Physics-Informed Neural Network for Fluid Flow Simulation in Heterogeneous Porous Media

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Numerical simulation is a vital tool for analyzing and predicting fluid flow in porous media. Physics-Informed Neural Networks (PINNs) can work out systems of partial differential equations (PDEs) by leveraging the universal approximation ability of Neural Network (NN), offering a novel approach for numerical model solving. However, current PINN-based methods are rarely used to simulate heterogeneous problems, especially in the coordinate-to-pressure mapping, where the training is challenging and the output accuracy is insufficient. In this work, we propose an Anchored Physics-Informed Neural Network (A-PINN) to tackle these problems involving complex physical backgrounds. Specifically, heterogeneous permeability fields are generated by Stanford Geostatistical Modeling Software (SGeMS). Boundary conditions are incorporated into the training process as hard constraints. The loss function is constructed by Finite Volume Method (FVM), which fixes the sampling points and eliminates the need for labeled data. We innovatively design an Adjacency-Location Anchoring(ALA) structure, which enhances the network interpretability by incorporating physical significance into the NN. Additionally, the ALA possess regularization ability during the updating of network parameters. Finally, we simulate multiple heterogeneous reservoirs to verify the superiority of A-PINN in solving complex problems. The new method can achieve sufficient accuracy and significantly improve the training speed.

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