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Physics Impact on Deep Neural Networks for Multiphase Flow in Porous Media

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Many recent studies have demonstrated the superior predictive interpretability and physics consistency by anchoring deep feedforward neural networks (DNN) with physics laws. As this type of network is fully connected, it potentially suffers low training efficiency when predicting complex problems such as multiphase flow in porous media.

In this study, we propose a learning framework to predict the state variables of pressure, saturation and well flow rate in fluid flow in porous media. Since fluid flow in porous media is constrained by physics, we allow the learning framework to flexibly intake either pure labeled data, or a combination of labeled data and physics data in terms of governing equation or physics-based operators. Given that the loss evaluation of non-labeled data during backpropagation is expensive due to automatic differentiation, a modified batch-mode training procedure with transfer learning is proposed to ensure that it balances the training efficiency and the contribution of all the samples on the training loss. As well flow rates are time series data only associated with well locations, it is effectively predicted along with pressure and saturation by a simple sparse operator in the same framework.

Numerical experiments of multiphase flow related to geologic carbon storage are used to gauge the performance of learning framework. Our results show that DNN integrating labeled data with physics or the physics-based operators doesn't bring too much additional CPU cost due to automatic differentiation, but they effectively improves the fidelity of pressure and saturation prediction compared to DNN with labeled data only. Moreover, the prediction of the well flow rate is quite accurate with average error lower than 2.0%. Therefore, the learning framework helps us to investigate the impact of physics on DNN predictions, and provides us the guidance to effectively train a DNN with a good combination of physics and labeled data.

Time Block Preference

Time Block C (18:00-21:00 CET)

References

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