Title: Deep Learning–Assisted Multiobjective Optimization of Geological CO_2 Storage Performance under Geomechanical Risks

Abstract

In geological CO_2 storage, designing the optimal well control strategy for CO_2 injection to maximize CO_2 storage while minimizing the associated geomechanical risks is not trivial. This challenge arises due to pressure buildup, CO_2 plume migration, the highly nonlinear nature of geomechanical responses during CO_2 injection on rock-fluid interaction, as well as the high computational cost associated with coupled flow-geomechanics simulations. In this talk, I introduce a novel optimization framework to address these challenges. The optimization problem is formulated as follows: maximize total CO_2 storage while minimizing geomechanical risks by adjusting the injection well's bottom-hole pressure (BHP) within bounded constraints. The geomechanical risks are primarily driven by injection-induced pressure build-up, which is characterized by the seismic moment. We employ the Fourier Neural Operator (FNO) based deep learning model to construct surrogate models, replacing the time-consuming coupled flow-geomechanics simulations for evaluating the objective function. The input features of the FNO-based proxy model comprise flow properties and well controls. Meanwhile, the outputs consist of time-series reservoir pressure and CO_2 saturation as the state variables. The FNO-based proxy model is trained on a synthetic case simulating large-scale CO_2 storage. The results demonstrate that the deep learning-based proxy models accurately and efficiently predict the designated state variables. The developed proxy models have been incorporated into a multi-objective optimization framework through a Genetic Algorithm (NSGA-II) to reduce the computational burden.

Fangning holds a Ph.D. in Petroleum Engineering from the University of Southern California (USC), where her research focused on CO_2 storage, including reservoir simulation, field-scale optimization, geomechanical risk assessment, and machine learning. During her doctoral studies, she developed a coupled flow-geomechanics-fracturing model to optimize well control and placement, aiming to maximize CO_2 storage while mitigating risks such as ground uplift, induced seismicity, and caprock fracturing. Following her Ph.D., Fangning joined Los Alamos National Laboratory, where she built a surrogate model for CO_2 storage using deep U-Net neural networks and Fourier Neural Operators (FNO). She later joined Zanskar Geothermal & Minerals, contributing to the development of a machine learning–accelerated optimization framework for geothermal exploration with faulting system. In addition to her Ph.D., Fangning holds dual master's degrees in Petroleum Engineering and Computer Science from USC.