Machine Learning for Porosity and Absolute Permeability Prediction from Carbonate Rock Images

Ramanzani Kalule[1*], Hamid Abderrahmane[2], Waleed Alameri[3], Mohamed Sassi[4]

[1,2,4*]Department of Mechanical Engineering, kramanzani@gmail.com
[3*]Department of Petroleum Engineering, Khalifa University, UAE

Abstract— Several empirical or theoretical models have been proposed in the literature to predict or correlate porosity and permeability [1] and other reservoir-based properties, their generalizability is still quite prohibitive [2]. This is because several reservoir property relationships are highly complex and nonlinear. Properties such as permeability cannot accurately be estimated using simplified or linear relationships [3]. The nonlinear relationship can make the estimates of rock properties using linear relationships inaccurate. Numerous machine learning (ML) models and deep neural networks (DNN's) have been reported to accurately handle nonlinear relationships in various scientific studies [4]. Several successful studies on predicting porosity and absolute permeability using ML or DL have been reported in the literature.

This study presents the capabilities of various machine learning-based regression algorithms in predicting rock porosity and absolute permeability from carbonate rock images. We adopt an ensemble learning approach, stacking that integrates predictions from several machine and or deep learning-based models into a single model to accelerate predictions and generalizability. Stacking is presented in two different ways with one based on typical ML models and the other designed with multiple DNN models of various architectural designs. The ML models adopted are both linear and non-linear including multiple linear, ridge, lasso, random forest, and gradient boosting regression models. We also adopt the use of the randomized search algorithm for optimal hyperparameter search over a wider hyperparameter space for each of the models. Our dataset is a set of micro-CT images scanned at different resolutions, from four different carbonate core samples. The selected rock samples exhibit different levels of heterogeneities and a wide range of absolute permeability. Averaged rock pore properties are extracted from each of these images using a watershed-scikit-image technique to represent the input features to the selected models. Results obtained from this study, show that both stacking approaches proposed can outperform the individual selected models. However, stacked ML models require more computational time, in contrast to stacked DNN's and the individual ML and DNN-based models. Concerning the individual models, we note that linear models are not able to generalize the dataset while nonlinear models require higher computational time than linear and DNN models. The trained individual models and the proposed ensembled stacked models predict the rock porosity and absolute permeability accurately in a few seconds. The study provides a valuable approach for predicting rock sample porosity and absolute permeability from several rock image samples within seconds.

References

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