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Hybrid Intelligent Algorithm for Permeability Estimation Based on Particle Size Distribution and Porosity Data

Hossein Izadi[1], Vahidoddin Fattahpour[2], Morteza Roostaei[2], Mahdi Mahmoudi[2], Juliana Leung[1], Noel Devere-Bennett[3]

1: University of Alberta, 2: RGL Reservoir Management, 3: CNOOC

Summary

Permeability is one of the most important features for reservoir characterization. The correlation between permeability versus particle size distribution (PSD) and porosity is widely acknowledged in oil-sand reservoirs. PSD is a main physical property in oil-sands, and it is an important variable in many complex hydrological, geological, and geophysical processes. Developing a relationship for permeability estimation based on such fast-gathering and low-cost data, namely PSD and porosity measurements, offers a cost-effective alternative for permeability predictions, as well as surveying permeability variations in a large-scale study.

In the literature, many investigations have been carried out for developing a relationship between permeability versus PSD and porosity (Arshad et al., 2019). However, the literature lacks the application of machine learning algorithms in developing such relationship.

We have applied "Genetic Binary Particle Swarm Optimization Algorithm-GBPSO", a previously developed intelligent and hybrid unsupervised learning algorithm, to estimate permeability (k) based on PSD characteristics, namely D_5, D_{10}, and D_{60} for situations where porosity (ϕ) is known (Eq. 1), or for cases in which porosity is unknown (Eq. 2).

$$k = aD_5^2 + bD_{10}^2 + cD_{60}^2 + \frac{d\phi^e}{f + \phi^g} \qquad Eq.1 \qquad\qquad k = aD_5^2 + bD_{10}^2 + cD_{60}^2 \qquad Eq.2$$

In the proposed expressions, a, b, c, d, e, f, and g are empirical coefficients and are optimized using the GBPSO to reduce the relative error between the estimated permeability and the experimentally measured ones. Our proposed expressions demonstrate superior predictions in comparison with the currently available relationships in the literature. Based on the experimental results, the higher the measured permeability the lower the uncertainty on the modelled permeability.

Theory / Method / Workflow

The Particle Swarm Optimization (PSO) is an adaptive algorithm to simulate social behavior of a group of agents. Each agent (here is a vector consisting of coefficients of Eq. 1 and 2) is represented in a multidimensional search space. In each generation (iteration), every single agent updates its velocity vector based on its current velocity, and the distance from its best and global best previous positions. In GBPSO algorithm, Genetic Algorithm (GA) is involved to create the next generations, achieving a more reliable evolutionary process (Sadri and Suen, 2006). Accordingly, new agents in each generation are created based on GA's operations, and for eliminating agents, random agents are removed via the process of accident.

After obtaining the optimized coefficients for the whole database, to investigate the effect of fines content, we divided the database into three groups based on varying levels of fines content: less than 10%, less than 20%, and less than 30%. Then, the coefficients of the relationships (Eqs. 1 and 2) are optimized for each case, as well.

Results, Observations, Conclusions

We have compared geometric mean of our result's relative errors versus the popular relationships proposed in the literature for permeability prediction (Fig. 1). Decreasing the fines content, generally, the estimation is more reliable (Fig. 2). As shown in Fig. 3, the estimation shows good agreement with the measured permeability values.

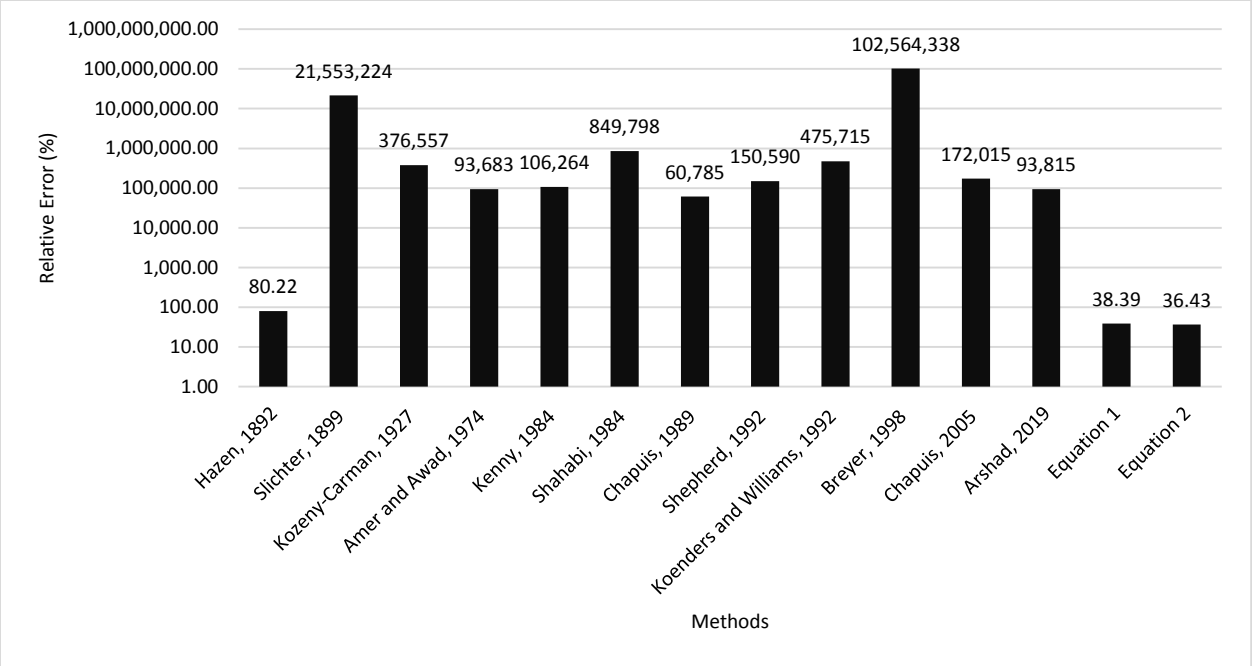

Fig. 1. Comparison of the developed model in this study and the relationships proposed in the literature

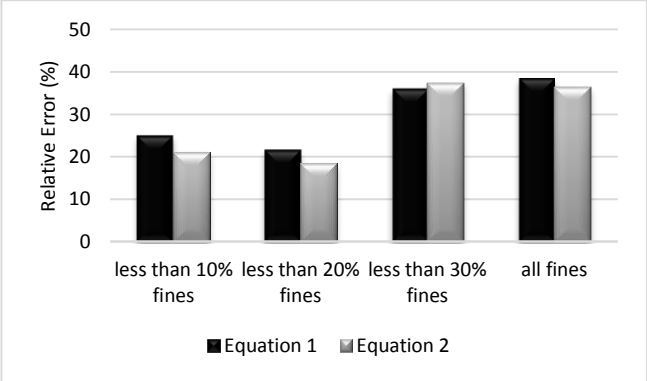

Fig. 2: Increasing the reliability by decreasing the fines content

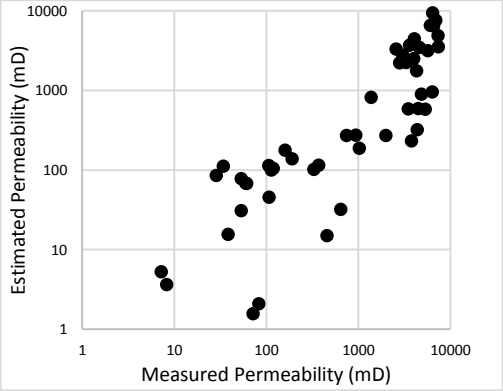

Fig. 3. The correlation between measured and estimated permeability (Eq. 2)

The optimized coefficients, in case of all fines contents are used for the estimation, are also provided for Eq. 1 and 2 in Tables 1 and 2, respectively.

Table. 1. Optimized coefficients for the Eq. 1

Table. 2. Optimized coefficients for the Eq. 2

a	b	c	d	e	f	g
0.092	0.241	0.003	0.010	-0.161	3.086	1.454

a	b	c
0.718	0.005	0.012

Novel/Additive Information

The novelty of this paper is two folds. The first one is that a new relationships for permeability estimation is developed based on a hybrid intelligent algorithm. The second one is that the proposed expressions enables one to estimate permeability based on such fast and low cost measurements as PSD.

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