University of Stuttgart
Germany

Department for Stochastic Simulation
and Safety Research for Hydrosystems (IWS)

Chair of Continuum Mechanics (MIB)

Discovery of Capillary Pressure – Saturation Relationships with Artificial Neural Networks

M.Sc. Topic

Relations between capillary pressure (p^c) and phase saturation (s) are often used as "closure equations" in models for two-phase flow in porous media. Numerous empirical $p^c(s)$-relations have been proposed such as the Leverett j-function, the van Genuchten relation, and the Brooks-Corey equations. All these "closure" equations come with various assumptions and are not aiming at modeling physical phenomena at the pore-scale. In many cases, these assumptions are not met, and models using these relations fail.

Recently, data-driven models have gained significant popularity due to their ability to learn features from real (e.g. experimental) data, as well as due to the vastly increased computing capacity of modern computers. One of the most popular data-driven methods is the Artificial Neural Network (ANN), and many variants of ANN have been developed to make them interpretable, physics-constrained, more similar to classical ordinary differential equations, and aware of their residual uncertainty.

In this Masters' thesis, we want to learn relations between capillary pressure and phase saturation from pore-scale-resolved experimental data using ANNs as the learning tool. Because the experiments are performed under dynamic conditions and there will be remaining uncertainties, we will use the Bayesian Neural Ordinary Differential Equation (Bayesian Neural ODE) method, specifically, to learn the differential equations that govern the processes taking place during the experiments and to quantify the uncertainty of the network prediction.

Prospective Tasks

- Literature review of two-phase flow in porous media, Neural ODEs, and Bayesian methods
- Understand the (pore-scale) experimental data
- Refine and train a Bayesian Neural ODE using the experimental data
- Quantify the predictive performance and uncertainty

General Information

- Advisors: Timothy Praditia, M.Sc., Samaneh Vahid Dastjerdi, M.Sc., apl. Prof. Dr.-Ing. Sergey Oladyshkin, Dr. Nikolaos Karadimitriou, Prof. Dr.-Ing. Wolfgang Nowak, Prof. Dr.-Ing. Holger Steeb (i.e. a mix of fluid mechanics, porous medium scientists, statisticians and ML researchers)

Desirable skills

- Good knowledge on mathematics and Bayesian statistics (and preferably ANN)
- Affinity to numerical simulations and programming (Python / Julia)

Apply now!
timothy.praditia@iws.uni-stuttgart.de

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