UNIVERSITÉ DE STRASBOURG

Institut Terre & Environnement de Strasbourg | ITES | UMR 7063

TU BERGAKADEMIE · FREIBERG ·

Master Thesis

Artificial Intelligence in Physics and Engineering:

A new implementation of deep convolutional neural networks for modeling transient natural convection in porous media

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Is this for you?

You're interested in new methods of artificial intelligence (AI) and machine learning (ML)? You want to apply them to solve physical problems? You have a background in engineering, natural sciences or mathematics and like working with computers? You would like to work in an international environment and improve your language skills? Then take a look at the project description below. Don't be scared by all the new words and contact us in case you're interested to learn more about the topic.

You will stay partially in Freiberg/Germany, and partially in Strasbourg/France. The candidate will receive 600 €/month during 5 months from the university of Strasbourg.

The topic

Deep learning neural networks (DLNNs) have yielded innovative/transformative results in diverse scientific disciplines. Application in geosciences and hydrogeology is, however, still at the developing stage. Thus, it is important to evaluate the performance of these new approaches in the context of physics-based models. Remarkably, both observation and simulation data can used to train DLNNs and to develop efficient and robust models that can assist or replace mechanistic models in developing prediction studies. Several studies used DLNNs as surrogate models to replace mechanistic models in applications involving repetitive simulations such as parameter estimation, uncertainty analysis or optimization problems (Mo et al., 2019; Tahmasebi et al., 2020). They showed that, compared to traditional and standard interpolators, DLNNs are more robust in representing complex nonlinear processes, capturing hidden information, and learning advanced representations.

Encoder-Decoder Convolutional Neural Networks (ED-CNNs) are a specialized DLNN architecture well-suited for image-to-image regression. Recently, Rajabi et al. (2021) investigated the performance of ED-CNNs, as a specialized deep learning architecture, in assisting the procedure of numerical modeling of natural convection in porous media. In that paper, the ED-CNNs are applied to develop a methodology for image-to-image regression.

The performance of the ED-CNNs is investigated in meta-modeling and as optimizer for input parameter estimation. The results show better performance of the ED-CNNs in meta-modeling than in parameter estimation. The study by Rajabi et al. (2021) is limited to steady state configurations. It is expected that better performance of the ED-CNNs in parameter estimation can be obtained with transient data that could be more sensitive to heterogeneity than steady state configurations. Thus, the objective of this study is to evaluate the performance of the ED-CNNs in in assisting the procedure of numerical modeling of transient natural convection in porous media. The methodology is as following:

- Selecting a relevant benchmark for natural convection in porous media
- Developing a numerical model for this benchmark with the software OpenGeoSys.
- Generating data with transient simulations and understanding the best strategy to manage this data with ED-CNNS
- Applying ED-CNNs as surrogate model and evaluating its performance
- Applying ED-CNNs as optimizer for parameter estimation and evaluating its performance

References:

Rajab et al. (2022) Analyzing the efficiency and robustness of deep convolutional neural networks for modeling natural convection in heterogeneous porous media, International Journal of Heat and Mass Transfer 183 (2022) 122131 https://doi.org/10.1016/j.ijheatmasstransfer.2021.122131

Mo et al. (2018) Deep autoregressive neural networks for high-dimensional inverse problems in groundwater contaminant source identification, Water Resour. Res. 55 (5) (2019) 3856–3881.

Tahmasebi et al. (2020) Machine learning in geo-and en- vironmental sciences: from small to large scale, Adv. Water Resour. (2020) 103619.