Parameter estimation for unsaturated flow with an efficient encoder-decoder convolutional neural network

Mohammad Reza Hajizadeh Javaran[1], Mohammad Mahdi Rajabi[1], Benjamin Belfort[2], Marwan Fahs[2]
[1]Civil and Environmental Engineering Faculty, Tarbiat Modares University, PO Box 14115-397, Tehran, Iran.
[2]Université de Strasbourg, CNRS, ENGEES, ITES UMR 7063, 67000 Strasbourg, France.

Content:

Variably saturated flow in porous media is an important process of interest in many applications related to agriculture, geotechnics, sustainable water resources management. Its modeling has great issues in engineering and research & development, and the use of the "quite classical" model combining the Richards' Equation (RE) and constitutive laws (e.g., van Mualem – van Gencuhten or Brooks – Corey) remains a delicate challenge due to the necessity to deal with complex geometries, large space and long time simulations, variable boundary conditions, and often high non-linearities occurring in the simulations. Besides, hydraulic parameters related to the porous media have to be defined as input parameters of the computational model (Rajabi et al., 2020). This characterization - i.e., parameter estimation - can be achieved by inverse modeling approach, and in the context of unsaturated flow, many studies have tried to estimate these input parameters using different methods such as cloud computing and data-driven models. In this work, we aim to investigate the performance of the encoder-decoder convolutional neural network (ED-CNN) (Rajabi et al., 2022) as an optimizer tool to estimate the input parameters of flow employing the concept of *image to image regression* using input-output pairs through a supervised learning process. Input-output couples include maps of water content during an unsaturated flow experiment and parameters maps, respectively. Images of 3 relevant parameters, including k_s, which is saturated conductivity, α, the parameter related to the mean pore size, and *n*, the parameter reflecting the uniformity of the pore size distribution, are combined in a single parameters map. The training dataset is generated and then stored as PNG images using a numerical code based on RE which simulates the drainage phase of the laboratory experiment carried out by Belfort et al. (2019). The ED-CNN is then trained and evaluated using different evaluation metrics such as root mean squared error (RMSE) and relative errors. RMSE for k_s, α, and *n* is about 0.14, 0.12, and 0.12, respectively. Moreover, the relative error amount is 0.07, 0.03, and 0.02 for estimated parameters, respectively. Hence, to further assess the efficiency of the network as an optimizer, we compared real maps of parameters with ED-CNN predictions. We got a good agreement between them and low relative errors. The network's accuracy and speed revealed promising results as an inverse modeling tool for a transient simulation, indicating its potential for future subsurface and groundwater engineering applications and any other image-based kind of data.

References

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