Multiple-point statistics simulation and inversion using a spatial generative adversarial neural network

Eric Laloy, Belgian Nuclear Research Centre,
Romain Hérault, INSA Rouen, Niklas Linde, University of Lausanne

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Abstract

Probabilistic inversion within a multiple-point statistics (MPS) framework is still computationally prohibitive for high-dimensional problems. Here we introduce and evaluate a new training-image based simulation and inversion approach for complex geologic media [1]. Our approach relies on a deep, spatial generative adversarial network (SGAN). After training using a training image (TI), our proposed SGAN can quickly generate 2D and 3D unconditional realizations. A key feature of our SGAN is that it defines a (very) low-dimensional parameterization that follows an uniform distribution. This enables efficient probabilistic (or deterministic) inversion using state-of-the-art Markov chain Monte Carlo (MCMC) methods. Compared to our recent MPS inversion work with a deep neural network of the variational autoencoder type [2], our SGAN has the following advantages: (1) training the network can be performed using a single TI only, (2) it is fully 3D, (3) it can handle both binary and multi-categorical geological facies and, in principle, continuous data (e.g., hydraulic conductivity fields), (4) it is constructed such that each dimension of the latent space only influences a given fraction of the high-dimensional domain, and (5) it results into an even more compact representation of high-dimensional 3D domains with a dimensionality reduction that can exceed 4 orders of magnitude. A series of 2D and 3D categorical TIs is first used to analyze the performance of our SGAN for unconditional simulation. Training can last for several hours on a powerfull GPU. Yet once the network is trained, the high speed at which realizations are generated makes it especially useful for simulating many realizations over large grids and/or from a complex multi-categorical TI. Challenging synthetic inversion case studies involving 2D steady-state flow and 3D transient hydraulic tomography are then used to illustrate the effectiveness of our proposed SGAN-based probabilistic inversion. For the 2D case, our approach rapidly explores the posterior model distribution. In addition, the incorporation of direct conditioning data within the inversion is found to speed up convergence of the MCMC by 1.4. For the 3D case, the inversion recovers model realizations that fit the data close to the target level and visually resemble the true model well.

References

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