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Abstract

Generative Adversarial Networks (GANs) are one of the fastest growing applications of Deep Learning for image generation. GANs have proved very successful for generating two-dimensional stochastic images that are statistically representative of a large training set of images. The natural question to ask is whether GANs can be used to generate a priori reservoir models representative of the conceptual models produced by geologists, and whether there is an added value in using GANs rather than standard geostatistical approaches for reservoir applications. This paper documents several modelling applications of GANs and shows that indeed GANS can be successfully used to generate three-dimensional models, both at the pore and at the reservoir scale. Because GANs define a new parametrization of images based on a small set of latent random vectors, they provide a novel approach for constraining models by multidisciplinary data.

GANs transform latent Gaussian random vectors into simulated images thanks to a deep convolutional neural network called the Generator. The generated images are fed into another convolutional neural network, the Discriminator, which evaluates whether the generated images can be accepted as statistically representative of the set of training images. Numerous iterations are required until both the Generator and the Discriminator are trained in such a way that the Discriminator cannot distinguish images obtained by the Generator from the images of the training set. Once training is completed, the trained Generator can be used to create stochastic images using any realization of the Gaussian random latent vector as input. Are GANs capable of generating images of micron-scale porous media as well as images of reservoir-scale geological facies and petrophysical properties distributions?

An example based on a micron-scale carbonate sample shows that GANs generate three-dimensional models that share the same covariance, Minkowski functionals, permeabilities and flow velocities distribution as the original training image. The generation of micron-scale images can also be constrained by two-dimensional sections, leading to a set of possible micron-scale models all sharing the same cross-section.

At the reservoir scale, GAN-generated earth models can be constrained by well data and surface seismic, thanks to the latent vector parametrization of the GAN models. For instance GANs can generate a set of object-based facies models all constrained by seismic data (and wells) thanks to full waveform inversion combined with neural network backpropagation.

This paper shows that generative techniques based on Deep Learning such as GANs can be used to generate reservoir property models at all scales and that, thanks to the parametrization provided by the latent vector representation, these models can be constrained to a wide variety of data, including well data, cross-sectional information, seismic and possibly production data.