Multi-Scale 3D Carbonate Digital Rock Reconstruction: Traditional or Machine Learning Approaches?

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Abstract. This work aims to reconstruct multi-scale carbonate rocks using a model hybrid with Wasserstein generative adversarial network with gradient penalty (WGAN-GP) and variational auto-encoder (VAE). In particular, the WGAN-GP is trained to reconstruct macro-porosities, while the VAE reproduces microscopic porosity invisible in the μ-CT imaging process. The fine-scale structures are extracted from 2D SEM images by imposing a probability distribution on the latent space so that extracted features match input images. An automated workflow is proposed including dataset preparation, model training, and result screening. To obtain sufficient training datasets, we extract numerous subsamples from the original rock image with data augmentation techniques. To evaluate synthetic carbonate rocks, we compare both morphological and hydraulic properties of generated rocks with those of training samples. Morphological properties including two-point auto-correlation, Minkowski functionals and pore size distribution, are examined. In addition, we will calculate the single-phase effective permeability, relative permeability and capillary pressure to verify the connectivity and conductivity of synthetic rocks. It is observed that the combination of WGAN-GP with VAE shows great potential in reconstruction of multi-scale heterogeneous carbonate rocks. In contrast to other GANs using Jessen-Shannon divergence, the WGAN-GP honors a stable training even without any heuristics. Instead of frequently visual check of the training process, the loss curve of the discriminator provides an explicit indicator of the quality of the trained model.