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Solving the problem of imaging resolution: stochastic multi-scale image fusion

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Structural features of porous materials define the majority of its physical properties, including water infiltration and redistribution, multi-phase flow (e.g. simultaneous water/air flow, gas exchange between biologically active soil root zone and atmosphere, etc.) and solute transport. To characterize soil and rock microstructure X-ray microtomography is extremely useful. However, as any other imaging technique, this one also has a significant drawback – a trade-off between sample size and resolution. The latter is a significant problem for multi-scale complex structures, especially such as soils and carbonates. Other imaging techniques, for example, SEM/FIB-SEM or X-ray macrotomography can be helpful in obtaining higher resolution or wider field of view. The ultimate goal is to create a single dataset containing information from all scales or to characterize such multi-scale structure.
In this contribution we demonstrate a general solution for merging multiscale categorical spatial data into a single dataset using stochastic reconstructions with rescaled correlation functions. The versatility of the method is demonstrated by merging three images representing macro, micro and nanoscale spatial information on porous media structure. Images obtained by X-ray microtomography and scanning electron microscopy were fused into a single image with predefined resolution. The methodology is sufficiently generic for implementation of other stochastic reconstruction techniques, any number of scales, any number of material phases, and any number of images for a given scale. The methodology can be further used to assess effective properties of fused porous media images or to compress voluminous spatial datasets for efficient data storage. Potential practical applications of this method are abundant in soil science, hydrology and petroleum engineering, as well as other geosciences.
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