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Automatic parameter optimizer (APO) for multiple-point statistics

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Multiple Point statistics (MPS) have gained popularity in recent years for generating stochastic realizations of complex natural processes. The main principle is that a training image (TI) is used to represent the spatial patterns to be modeled. One important feature of MPS is that the spatial model of the fields generated is made of 1) the chosen TI and 2) a set of algorithmic parameters that are specific to each MPS algorithm. While the choice of a training image can be guided by expert knowledge (e.g. for geological modeling) or by data acquisition methods (e.g. remote sensing) determining the algorithmic parameters can be more challenging. To date, only specific guidelines have been proposed for some simulation methods, and a general parameters inference methodology is still lacking, in particular for complex modeling settings such as when using multivariate training images. The common practice consists in carrying out an extensive parameters sensitivity analysis which can be cumbersome. An additional complexity is that the algorithmic parameters do influence CPU cost, and therefore finding optimal parameters is not only a modeling question, but also a computational challenge. To overcome these issues, we propose the automatic parameter optimizer (MPS-APO), a generic method based on stochastic optimization to rapidly determine acceptable parameters, in different settings and for any MPS method.

The MPS automatic parameter optimizer proceeds in a 2-step approach. In the first step, it considers the set of input parameters of a given MPS algorithm and formulates an objective function that quantifies the reproduction of spatial patterns. The Simultaneous Perturbation Stochastic Approximation (SPSA) optimization method is used to minimize the objective function. SPSA is chosen because it is able to deal with the stochastic nature of the objective function and for its computational efficiency. At each iteration, small gaps are randomly placed in the input image. These gaps are then simulated using the chosen MPS method, with the remainder of the input image as TI. The objective function consists in mean square errors between the simulated and original gaps values. When no significant improvement can be brought to the parameters, the second optimization step uses a different objective function that aims at minimizing the CPU cost without degrading the spatial structures reproduction attained at step 1.

Different test cases show that MPS-APO is a useful and heuristic to automatically determine optimal parameters that offer good patterns reproduction with minimal computational cost. It increases the usability of multiple-point statistics for practical applications.