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A New Generic Method for Fast and Interactive Geological Models Perturbation

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SUMMARY

Geological models can be seen as images reproducing prescribed spatial features. Some interactive tools are introduced, which allow modifying images while preserving their main spatial structures. A perturbation is performed by applying the same transformation in all regions similar to a selected pattern within the image. Two types of transformation are proposed, consisting in directly changing the value of the variable, or in local magnifications. These methods can be applied to categorical and continuous variables and are useful tools for improving the conditioning to hard and soft data.
Introduction

Reservoir characterization involves geological models that reflect knowledge about the subsurface. Such geological models can be seen as images reproducing prescribed spatial features, and accounting for available information such as local conditional data, proportion constraints, or known geophysical responses.

Many approaches can be used to generate geological models, but whatever the method used, honoring all input data simultaneously is often a real challenge, and one has to find a compromise in terms of respecting the various sources of information.

In this presentation, we introduce some interactive tools allowing modifying images, while preserving their main spatial structures. The idea is to perturb an image by applying the same transformation in all regions similar to a selected pattern within the image (Brooks and Dodgson 2002). The perturbations consist in directly changing the value of the variable, or in local magnifications. The type and magnitude of the transformation are controlled by the user. These methods can be applied to categorical and continuous variables and are very fast in terms of computational time, therefore allowing to interactively perturb an existing geological model.

Methodology

The method is illustrated in Figure 1 and proceeds as follows.

First, the user selects a region in the model, which defines a reference pattern. Then, a dissimilarity map is computed by convolution: a distance between the reference pattern and the pattern of same geometry centred at each node of the image is calculated. This map is then thresholded to determine which regions of the image are similar to the one selected by the user. Finally, a specified transformation is applied to the regions considered similar.

Two possible transformations are proposed. The first one simply consists in changing the value of the variable attached to the nodes of the similar region. This operation requires a target value and is straightforward. The second one consists in a space deformation: the selected regions are magnified by a specified factor which can correspond to an expansion or a compression. To do this, 1) a balanced target magnification field is built, 2) the grid points of the image are moved accordingly (Keahey and Robertson 1997), and 3) the values of the variable known at the new locations are interpolated onto the original grid.

The approach is termed self-similarity-based because it relies on a distance to a pattern that already exists in the image. It is applicable in both 2D and 3D and allows accounting for conditional data: conditioning locations are preserved while the transformation of the image is performed. The transformations can be global or can also be restricted to a specific region of the model.

Discussion and conclusion

The main advantage of the proposed method is its generality and rapidity. It allows perturbing geological models that have been constructed with any type of method provided that they are described on a grid. The rapidity of the method allows using it in an interactive manner. As an application example, we will show how these tools can be used to edit a training image prior to running multiple-point statistics simulation. Furthermore, the applications possibilities are very broad: it offers a general way to perturb a model for history matching or to improve the conditioning of object-based models to hard data.
Figure 1 Illustration of image edition by space deformation: a) initial geological model with selected region (red box); b) normalized dissimilarity map; c) position of the new grid nodes locations for a magnification factor of 2.0; d) resulting image after perturbation.

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References
