An Automatic Approach to Stochastic Model Regridding

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In practice, the generated geostatistical realizations often model relatively large geological areas. It is very common that sometimes some smaller areas in the model are of more interest. This necessitates modeling the small area at a much higher resolution compared to the available coarse simulated values, which is in effect spatial downscaling. In this work, we practice downscaling using considerable amount of conditioning data at the coarse level of simulation. Spatial characteristics of the model will be restricted to the area of interest, and geostatistical models are generated accordingly at a much finer grid relative to the original grid sizes. This work is intended to provide a framework in an automated way to minimize user intervention. The strong conditioning of simulated data would be an advantage to the downscaling of this work while still the spatial data properties of the data should be considered locally (e.g. variogram).

Motivation

Regridding realizations has been long considered and required in geostatistical work. The basis of this work is similar to (Deutsch and McLennan, 2005) where McLennan has briefly discussed regridding by providing an example which re-simulate the facies and porosity at finer grids of a small region. This work attempts to establish a solid automated procedure through simplifying downsampling. In our work, conditioning data is very well configured, extracted from a prior simulated realizations. The high resolution model is generated simulating values for intermediate grids in the coarse grid interval. This provides the practitioner with a much more detailed analysis of the particular area. The new information on refined area could be used directly in postprocessing, ranking of realization and recovery decision making. Note that we work with point scale simulated values and every grid node is exactly defined at a point rather than over an interval or a block. In the regridding approach, the new simulated values define the corresponding properties for the grid nodes placed at specific distances between the old ones. In other words, attempts are made to reconstruct the geological attributes with large amounts of support information.

After extracting the area of interest and getting the data statistics associated with that region, two different approaches could be taken to assign the grids with corresponding attributes. The simplest is to apply the nearest neighbour ap proach and define every new grid point in a deterministic way. Depending on which data the grid point is closer to, it is described with the same data. Simulation, however, fill up the grid points through a stochastic process and numbers of realizations could be generated to describe the uncertainty at a higher resolution.

Here, we try to provide this geostatistcal workflow in an automated way (ultimately all in a script) with the hope that the practitioner is spared the tedious work of re-simulating the extracted area. Also, this is a reliable process of generating finer grid simulation compare to deterministic approaches such as nearest neighbor, as it tends to create artificial continuity of the structures. Moreover, the resulting finer grid resolution could be used as a valuable input to ranking and post processing of geostatistical models.

Plan

The ultimate automatic script of re-simulation of high resolution models is an ongoing process at this point. Some preliminary results will be provided as we proceed further. However, the entire work is planned to be more accessible and user-friendly as we develop this work. Carefully developed series of programs and tools linked by a script will be the final stage of this process. The version which exists at this point could be considered Version 0.1. The program is developed iteratively and new considerations will be taken into account as required. The final tools of this work is meant to be automatic, although some diagnostic and checking of results would be preserved. Necessary recommendations and suggestions would follow the process to help the user to go through post processing stages.

Workflow

The first step of automating the process to generate higher resolution models is to enable the user to extract the data of the area of his/her interest. For this, the user is required to determine a few parameters: length of area of interest in the X direction, length of area of interest in the Y direction, the rotation angle (defined

as positive if clockwise, starting at origin), the depth of elevation by determining the minimum and maximum levels at Z, the number of realizations to be considered, and how many realizations per initial realization to be generated. The program, called ``DataExtraction,'' is developed to extract the area of interest according to the requirements. The user should also specify the number of refined grids in the X and Y directions and determine the size of the grid nodes as well. The program applies the re-simulation accordingly.

The parameter file below belongs to the ``DataExtraction'' program. This is the first developed program in this workflow and the user should have the most intervention at this point. ``DataExtraction'' provides the user with data statistics such as the number of extracted data and the new categorical proportions (in the case of categorical model). This information is needed when stochastic simulation of the refined grid nodes to to be applied.

<pre>
                         Parameters for DATAEXTRACTION
                         ****
        START OF PARAMETERS:
        Realization.out   - initial simulation data file
        1   - columns for the variable
        1   - number of initial realizations
        256   8.0   16.0   - nx,xmn,xsiz
        256   8.0   16.0   - ny,ymn,ysiz
        128   0.5   1.0   - nz,zmn,zsiz
        0   - categorical(=0) or continuous(=1) model
        ExtractedCoordinate.out   - rotated extracted data file with coordinates
        ExtractedData.out   - extracted data output file
        50   100   - new origin in X, new origin in Y
        30   - rotation angle (in degrees clockwise)
        30   80   - length for data extraction in X and Y direction
        50   51   - zmin, zmax for depth of data extraction
        3   5   - number of realizations to apply
        16   1.0   - numbers of refined grids, size of each grid node in X
        16   1.0   - numbers of refined grids, size of each grid node in Y
</pre>

Before applying the simulation, the horizontal and vertical variograms should be determined. A program called ``VariogramParameters'' is developed to prepare the required parameters for Gamv2004. This is specific to variogram parameters in the horizonal plain. The user should specify the number of directions that he/she wants the variogram to be calculated between 0°and 90°(program suggests using an odd number). The program calculates all the parameters of angle, tolerances, and distances for the specified direction from 0°to 180°. For example, specifying 5 as the number of directions results in 9 variogram specifications in the output file, starting from 0°to 90°. The corresponding parameter file is as follows:

<pre>
                       Parameters for VARIOGRAMPARAMETERS
                       ****
        START OF PARAMETERS:
        8.0   16.0   - xmn,xsiz
        8.0   16.0   - ymn,ysiz
        0.5   1.0   - zmn,zsiz
        40   80   - length for data in X and Y direction
        1   - depth of data in vertical direction
        5   - number of directions(XY plane) from 0 to 90 (3,5,7,..)
        varparameters.out   - variogram parameters for gamv2004
</pre>

Gamv2004 will determine the variogram based on the parameters specified. The program ``varfit'' will be applied to fit the variograms for all the existing categories. In the case of categorical model, SIS will be applied to define the refined grids stochastically, based on statistics of data (proportions) and calculated variograms.

A simple program called ``NearestNeighbour'' is also developed to assign the regrided nodes with the nearest indicator. This is applied to observe that the newly refined realizations using deterministic approach inherit sort of artificial continuity (the preserved edges are easy to be detected by eyes). The following parameter

file is used to apply nearest neighbour approach on extracted data.

```
                        Parameters for NEARESTNEIGHBOUR
                        *********************************
START OF PARAMETERS:
ExtractedCoordinate.out              - extracted data with coordinates
1                                    - columns for the variable
2    3    4                          - columns for x, y, z
4802                                 - number of extracted data
240    1.0    2.0                    - nx,xmn,xsiz
640    1.0    2.0                    - ny,ymn,ysiz
0.5    1.0                           - nz,zmn,zsiz
40    80                             - length for data in X and Y direction
1                                    - depth of data in vertical direction
5                                    - number of directions(XY plane) from 0 to 90 (3,5,7,..)
varparameters.out                    - variogram parameters for gamv2004
```

Example

A realization from the TI library has been selected to apply the downscaling procedure. The realization is the simulation of a Crevasee geological feature and has been originally generated with 256 grids in the X direction and 256 grids in the Y direction, with the grid sizes in both directions being 16 units. Also, there are 128 grid cells vertically, with a grid size of 0.156 units. We have applied our implemented downscaling process to the first slice of this realization and embedded the re-simulated figure at the end of this paper. The area of interest originates at x_{origin}=10 and y_{origin}=80. Data extraction is taken within a region of length of 70 in the X direction and 120 in the Y direction, with a rotation angle of 20°clockwise. The extracted data includes 4 categories of 0, 1, 2, 3, with the proportions of 73%, 16%, 9%, and 2%, respectively. After extracting the data, local variogram of 9 directions has been applied on the extracted data region. The parameters required for experimental variogram have been determined using ``VariogramParameters'' program for 9 directions. The fitted variogram is applied to process stochastic indicator simulation. The refined area has been simulated for 560 grid cells in the X direction and 960 in the Y direction. This implies that the extracted area is re-simulated at a higher resolution by a factor of 8. Figures 1, 2, 3 illustrate the above example.

Figure 4 shows the result of another example. The original data in the example is not an output from simulation just an ordinary image.

Discussion

The facility for regridding is intended to be simple and nearly automatic. At present, the programs are executed sequentially within a script. This way, the output of every program will be used as the input to the next program for further processing. This is aimed to make its usage as simple as possible and the user will be able to apply re-simulation on any number of areas at finer grid resolution. The procedure is not fully automatic. There are some considerations that should be taken into account by the user. For example, the user might perform some checking on the automatically fit variogram(s) and make sure things make sense. Some alternatives could also be considered depending on the judgment of user. For example, the original variogram may be taken for the extracted area. This may not be possible because the original variogram parameters may no longer be available. Also, adapting the variogram to local features may provide improved models.

Future Work

This work is designed to simplify the process of downscaling and to make the results more realistic than simply replicating values from a coarser scale. The goal is to achieve an automated process so that user intervention is kept to a minimum. The developed process is not yet complete, but the goal is robust parameter inference followed by realistic stochastic simulation. The regridding has to be applied to continuous variables. It will also be developed for multiple continuous correlated variables. The development of a plugin for widely used commercial software will be considered.

References

C. V. Deutsch and J. A. McLennan. Guide to SAGD reservoir characterization using geostatistics. In *Guidebook Series*, volume 3, page 121, University of Alberta, August 2005. Centre for Computational Geostatistics (CCG).
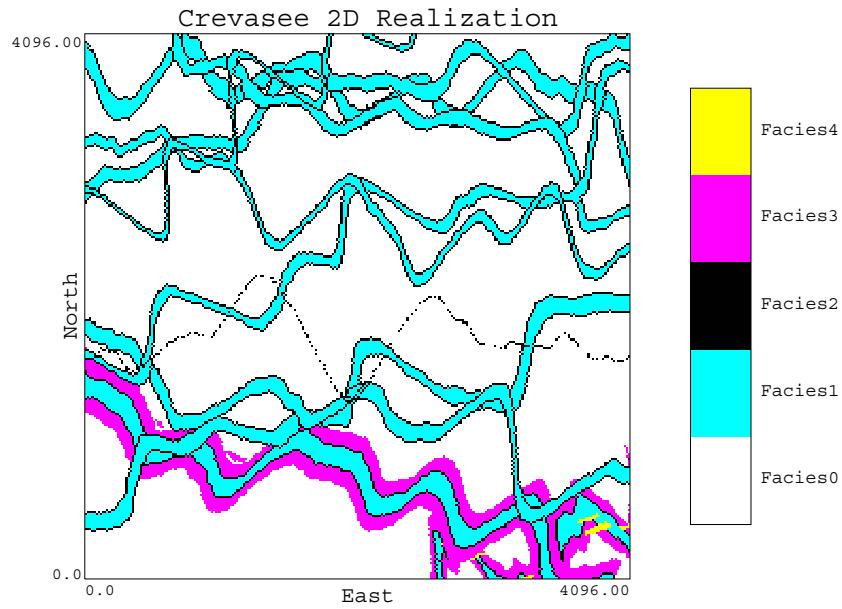

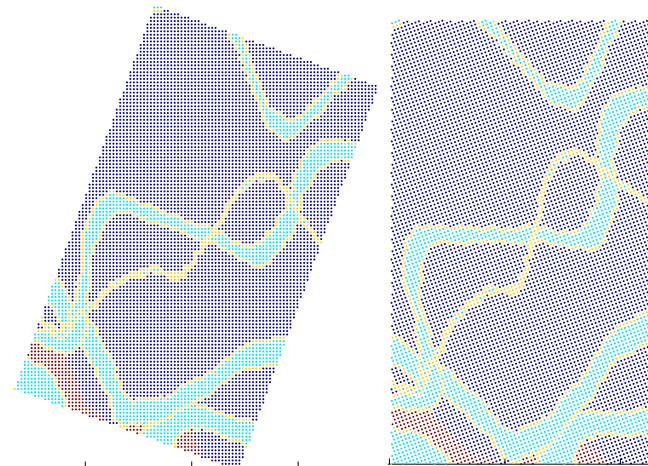**Figure 1:** Horizontal map of Crevasee realization from TI library (first slice).

Figure 2: Horizontal map of Crevasee realization from TI library (first slice).
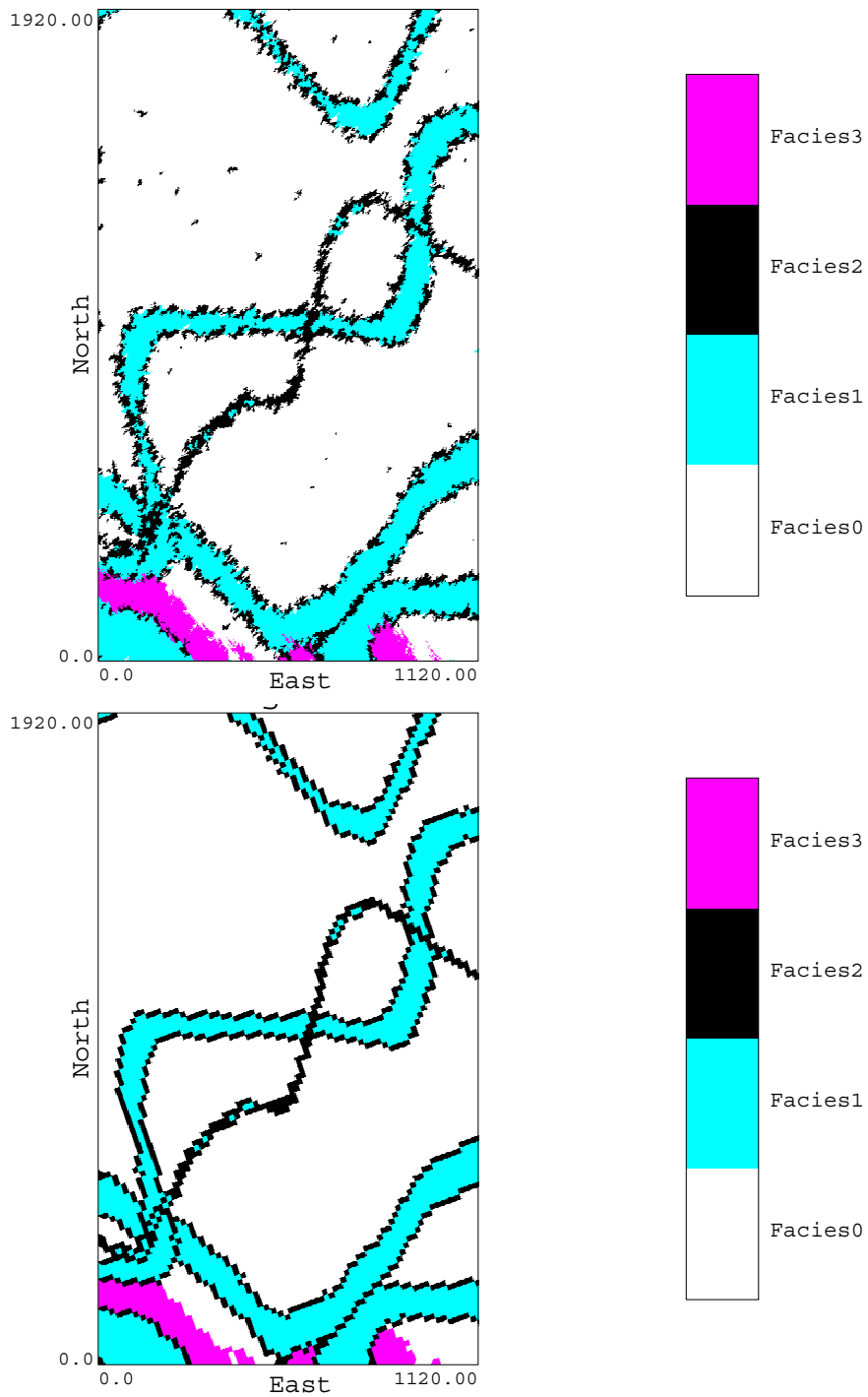
Figure 3: Top figures show the exracted data. The bottom figures illustrate the refined re-simulation of extracted data. The one at left result from stochastic simulation and the one at right result from nearest neighbor process.
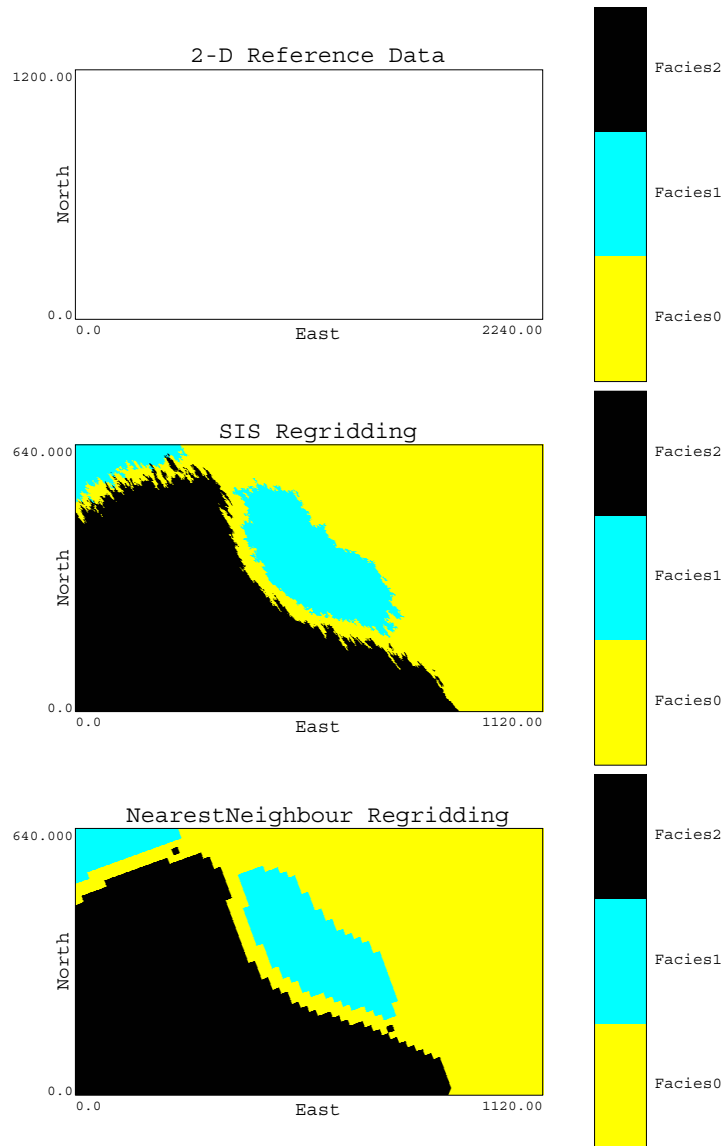
Figure 4: Illustrates the results of simulation for regridded region using stochastin (2nd) and deterministic (3rd) approach.