Including stratigraphic hierarchy information in geostatistical simulation: a demonstration study on analogs of alluvial sediments

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Introduction

Multiple-point statistics (MPS) is a geostatistical simulation technique that relies on a model of heterogeneity provided by a training image (TI). Outcrop analogs have been used as TIs with some success. However, they often present strong non stationarities that can be handled by considering auxiliary information (auxiliary variables), extracted for example from the results of geophysical surveys. When a geophysical surveys in not available, defining a reliable auxiliary variable can be difficult.

In addition, sedimentologists/geologists can extract important information about the stratigraphic hierarchy of the outcrop analog. This information cannot be directly included in the standard MPS techniques.

Here we propose a hierarchical MPS simulation procedure that allows to include the available information about the stratigraphic hierarchy, and can be used to tackle non stationarities when the definition of an auxiliary variable is not possible.

Many authors proposed hierarchical approaches using diverse simulation techniques; in a MPS framework, Maharaja and Journel [1] proposed a similar approach, which is here extended and tested with a different case study.

Data set

The proposed approach is tested using the data coming from a blocks of sediments extracted from a quarry in Northern Italy (Fig. 1), where Pleistocene sequences of the Ticino basin were thoroughly studied by Zappa et al.[2] (Fig. 2 and Fig. 3).

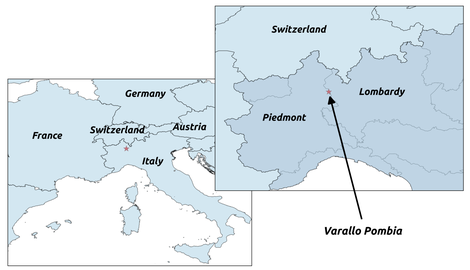

Figure 1: Location of the quarry where the model blocks were excavated.

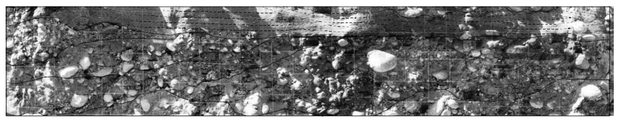

Figure 2: Photomosaic of one face of the block of sediments (face A).

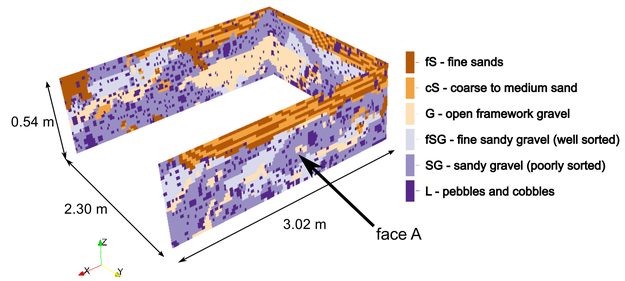

Figure 3: Hydrofacies classification of the block, discretized by 2 cm × 2 cm cells. Vertical exaggeration ×2

Methodology

The proposed hierarchical MPS simulation procedure can be summarized as follows:

1. Select an appropriate stratigraphic hierarchy of facies. Here we adopt the one proposed by Zappa et al.[2].
2. Define a **tree-like** simulation frame (Fig.4)

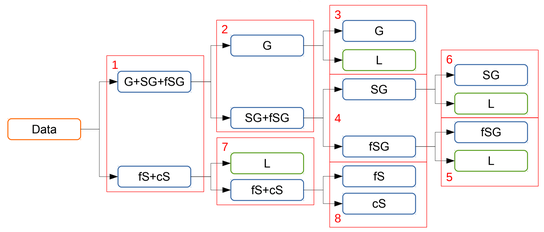

Figure 4: Stratigraphic hierarchy used to define the tree-like simulation frame.

3. For each branch, a binary training image (TI) is created simplifying the available data set (Fig. 5).

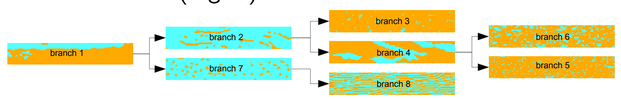

Figure 5: Binary training images used for the MPS simulation of each branch.

4. For each branch of the frame, a binary MPS simulation is performed.
5. Finally, all the results are merged back into the original facies codes.

References

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Results

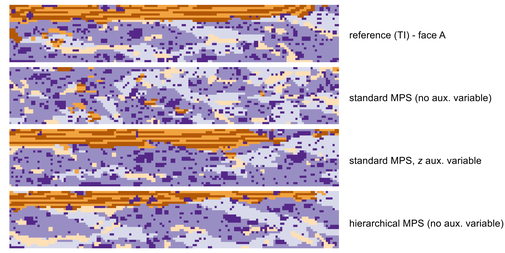

Figure 6: Comparing the reference TI with an standard MPS simulation, a standard MPS simulation with **z** as auxiliary variable and a hierarchical MPS simulation with no auxiliary variable.

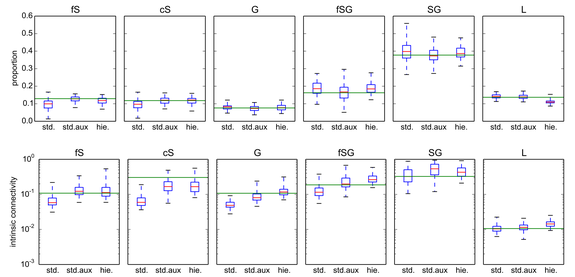

Figure 7: Proportions and intrinsic connectivity indicator (see Vassena et al. [3] for the definition) computed on 100 realizations simulated with standard MPS (std.), standard MPS with auxiliary variables (std.aux) and the proposed hierarchical MPS procedure (hie.). The green horizontal lines are the reference values computed on the TI.

Conclusions - Future work

- Both the proposed hierarchical MPS procedure and a standard MPS simulation with auxiliary variables can handle the non stationarities, but in a different fashion. The results obtained with the two techniques are comparable.
- The next step is to thoroughly test the approach in 3D and compare it with other techniques. The resulting 3D domains will be used as "virtual aquifer" where run flow and transport synthetic experiments.

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