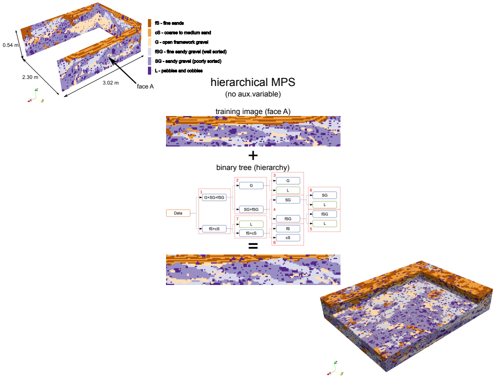
A hierarchical multiple-point statistics simulation procedure for the 3D reconstruction of alluvial sediments



Comunian A.[1], Bersezio R.[1,2], Felletti F.[1], Giacobbo F.[3] and Giudici M.[1,2,4]

1. Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Milan, Italy
2. CNR-IDPA (Consiglio Nazionale delle Ricerche, Istituto per la Dinamica dei Processi Ambientali), Milan, Italy
3. Politecnico di Milano, Dipartimento di Energia, Milan, Italy
4. CINFAI (Consorzio per la Fisica delle Atmosfere e delle Idrosfere), Tolentino (MC), Italy

42nd IAH CONGRESS — Università degli Studi di Milano, Dipartimento di Scienze della Terra "Ardito Desio" — National Research Council of Italy — Politecnico Milano 1863 — CINFAI — Consorzio Interuniversitario Nazionale per la Fisica delle Atmosfere e delle Idrosfere

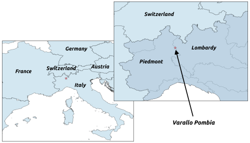


Figure 1: Location of the quarry where the model blocks were excavated.

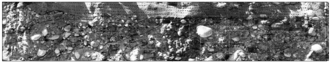


Figure 2: Photomosaic of one face of the block of sediments (face A).

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 the results of a geophysical survey are not available, defining a reliable auxiliary variable can be difficult.
In addition, sedimentologists/geologists can extract important information about the textural 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 textural 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 [2] 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 block 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.[4] (Fig. 2 and Fig. 3).

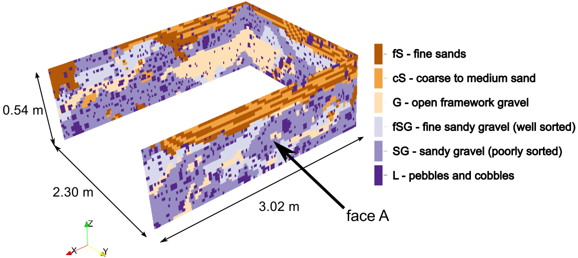


Figure 3: Hydrofacies classification of the block, discretized by 2 cm $\times$ 2 cm cells. Vertical exaggeration $\times 2$.

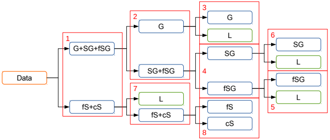


Figure 4: Textural hierarchy used to define the binary tree required by simulation procedure.

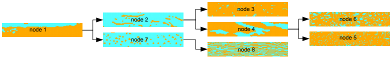


Figure 5: Binary training images used for the MPS simulation at each node of the binary tree. Here the TI are reconstructed using the available data.

Methodology

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

1. Select an appropriate textural hierarchy of facies. Here we adopt the one proposed by Zappa et al.[4], but the methodology is flexible and the hierarchy can be defined using different criteria (i.e. facies abundance, grain size...)
2. Translate the hierarchy in terms of a binary tree (Fig.4)
3. The available data are aggregated according to the defined hierarchy, and for each node of the binary tree a binary training image (TI) is created (Fig. 5)
4. For each node, a binary MPS simulation is performed in the portion of the domain defined by the simulation at the previous step. For example, the TI defined for the *node 2* (Fig.5) is used to simulate the heterogeneity in the *orange* portion of domain simulated using the TI at the *parent node* (*node 1*)
5. Finally, all the results are merged back into the original facies codes

Results

See the simulation results (Fig. 6) and the comparison with the reference training image in terms of proportions and connectivity indicators on 100 realizations (Fig. 7). Preliminary 3D results are reported in Fig. 8 (next page).

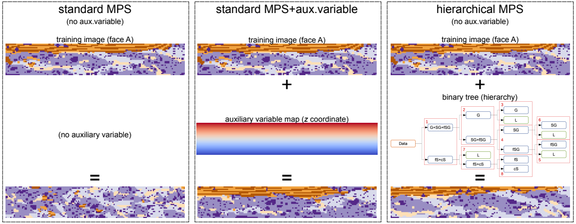


Figure 6: Results obtained with a standard MPS approach, a standard MPS approach using z as auxiliary variable, and the proposed hierarchical MPS approach. All the simulations are unconditional.

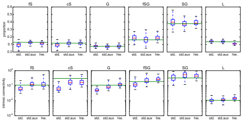


Figure 7: Proportions and intrinsic connectivity indicator (see Vassena et al. [3] for the definition) computed on 100 realizations simulated with standard MPS (std.), standard MPS with auxiliary variables (std.aux) and the proposed hierarchical MPS procedure (hie.). The green horizontal lines are the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

UNIVERSITÀ DEGLI STUDI DI MILANO
DIPARTIMENTO DI
SCIENZE DELLA TERRA "ARDITO DESIO"

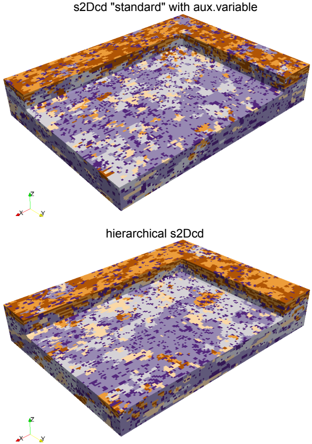


Figure 8: Some preliminary results obtained applying the `s2Dcd` approach, an approach that allows to obtain 3D MPS simulations starting from 2D training images (for more details, see Comunian et al. [1])

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 (some preliminary results are reported in Fig. 8). The resulting 3D domains will be used as "virtual aquifer" where run flow and transport synthetic experiments.

For more info...

Please don't hesitate to contact me: **Alessandro Comunian**, alessandro.comunian@unimi.it

References

[1] A. Comunian, P. Renard, and J. Straubhaar.
3D multiple-point statistics simulation using 2D training images.
Computers & Geosciences, 40:49–65, March 2012.

[2] A. Maharaja and A. Journel.
Hierarchical simulation of multiple-facies reservoirs using multiple-point geostatistic.
In *SPE Annual Technical Conference and Exhibition, 9-12 October 2005, Dallas, Texas*, 2005.

[3] C. Vassena, L. Cattaneo, and M. Giudici.
Assessment of the role of facies heterogeneity at the fine scale by numerical transport experiments and connectivity indicators.
Hydrogeology Journal, 18(3):651–668, 2010.

[4] G. Zappa, R. Bersezio, F. Felletti, and M. Giudici.
Modeling heterogeneity of gravel-sand, braided stream, alluvial aquifers at the facies scale.
J. Hydrol., 325(1-4):134 – 153, 2006.