Advanced Approaches in Geostatistical Reservoir Modelling - Methods and Benefits

Introduction

Geomodelling aims at representing as well as possible the reservoir heterogeneities in terms of lithofacies and petrophysical variables. Consequently, the modelling methods and their optimization play an important role for a refined and adequate modelling.
When modelling, the issues to tackle are, among others: the level of realism of the facies simulations, the conditioning of simulations to wells data and the spatial behavior (local anisotropy integration for instance). Several simulations methods are available either in geological modelling or in petrophysical modelling. All those methods have their pros and cons. For example, facies variogram-based methods as Sequential indicator Simulation (SIS), Plurigaussian simulation (PGS) are flexible but may not be able to properly represent connectivity in some cases. On the contrary, object-based methods (as Boolean) simulate connected bodies but the data conditioning is not easy. Multiple-points Statistics simulations (MPS), at the edge between pixel-based and object-based methods, may look more promising but needs reliable and consistent prior information for the facies distribution and relationships (geological training image).
This paper aims at combining several algorithms in order to benefit from their advantages and therefore optimize the modelling. The following workflow is proposed: first, a process-based algorithm for Meandering Channels simulations is run in order to generate realistic facies simulations. This geological information is then used as a training image for MPS simulations, allowing efficient data conditioning. Finally, locally varying anisotropies are integrated for ensuring a better continuity of porosity simulations in the main direction of each channel.

Material and modelling methods

The proposed modelling workflow relies on different approaches. Firstly Meandering Channels simulations are run, in order to reproduce a fluvial environment. Then, a geological information (training image) is extracted from one Meandering Channels simulation in order to be used as input in MPS simulations. Afterwards a porosity modelling is carried out, constrained by information retrieved from meandering channels simulation. A local optimization of the spatial parameters is done (local variogram anisotropies). These steps are detailed below and then applied on a synthetic dataset.

Meandering Channels simulations are based on a genetic (process-based) algorithm called FLUMY (Rivoirard et al., 2007) that simulate fluvial depositional environment system. Processes such as channel migration, overbank flood, levee breaching, water table can be reproduced during the simulation. Aggradations are setup during time in order to bring changes during the life of the depositional system. Such process-based approach gives realistic bodies and arrangements. The complexity of sand bodies and the contrast arrangements are reproduced, therefore producing geologically realistic simulations. However, although possible in some cases, data conditioning may be tricky with such algorithms.

MPS simulations are a simulation method that reproduces geological connected bodies (as channels) contained in a prior “training image” (Strebelle, 2000; Strebelle, 2002) The training image represents the geological context to be simulated. It can be either in 2D or 3D. It is derived from the geological knowledge of the reservoir. Analogs, outcrops, geological conceptual model can be used to build a training image. Geological bodies’ simulations (object-oriented simulations, meandering channel simulations) can also be used.

When running variogram-based simulations of porosity, a local optimization of the variogram (and neighborhood) parameters can be done. Local ranges, local anisotropies can be computed for each simulated node using the Local Geostatistics approach (Magneron et al., 2009). These parameters are integrated in the SGS algorithm. Local optimization allows integrating geological heretogeneities information. For example, the variogram main anisotropy direction will change according to the channel orientation. It allows to have a more accurate modelling and to reduce uncertainties.

Results

1) Meandering Channels simulations

Non conditional Meandering Channels simulations have been run using the FLUMY approach. A simple lithological model based on three lithotypes has been used (point bar, levee, overbank alluvium).

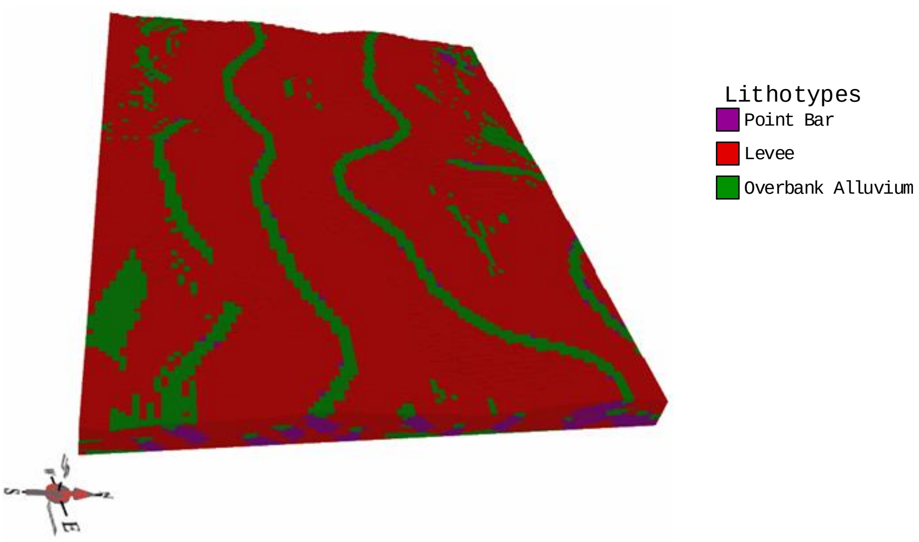

Figure 1: *3D Meandering Channels simulation.*

2) Geological information extraction

From 3D meandering channels simulations, 2D time slices are extracted. They are used for multiple-points simulations (as training image, see Figure 2 below) and for porosity modelling (see Figure 4 and Figure 5).

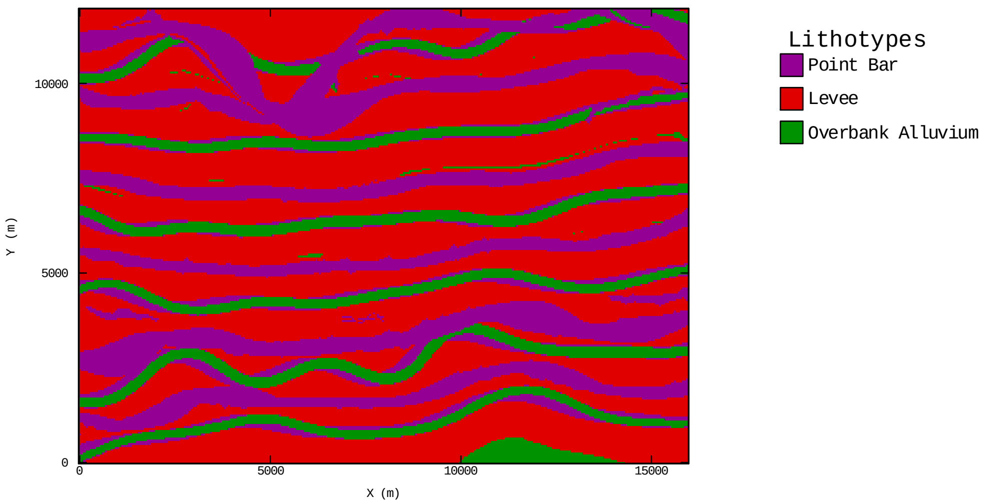

Figure 2: *2D Training image extracted from a meandering channels simulation.*

3) Lithofacies multiple-points statistics simulations

For illustration purpose, 2D simulations are carried out. The main point is to reproduce the connectivity of the channels visible in Figure 2, used as training image. Such MPS simulations can, by construction, easily be conditioned to honour input wells data.

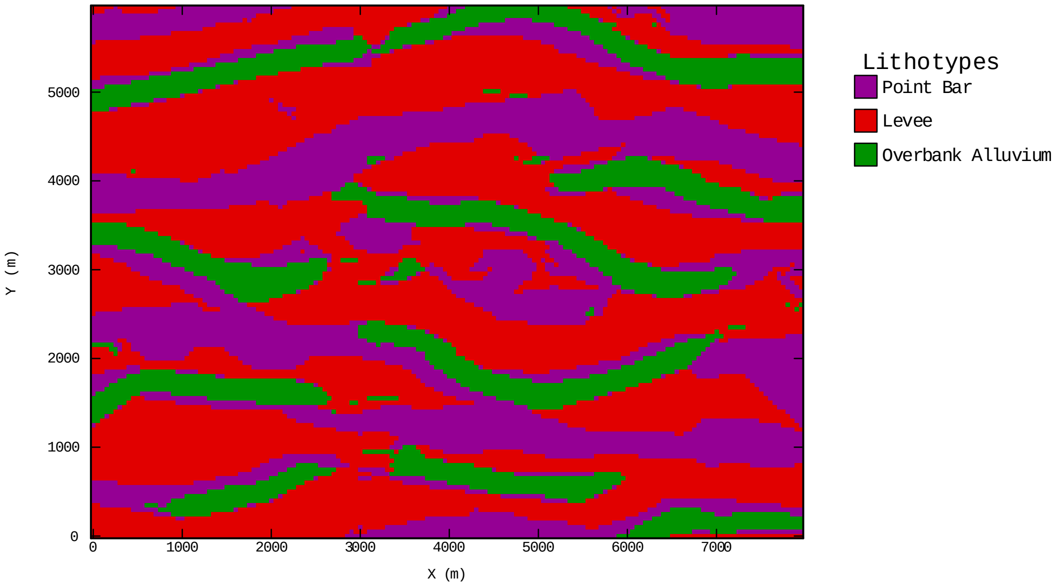

Figure 3: *2D Multiple-Points facies simulation.*

4) Porosity simulations with local optimization of geostatistical parameters

Channels paths have been extracted from a meandering channel simulation. Then the local azimuth has been computed along the channels through a local variogram cross-validation process. In that example, only one local parameter has been computed. But other local parameters (local ranges, local sills) could also be used.

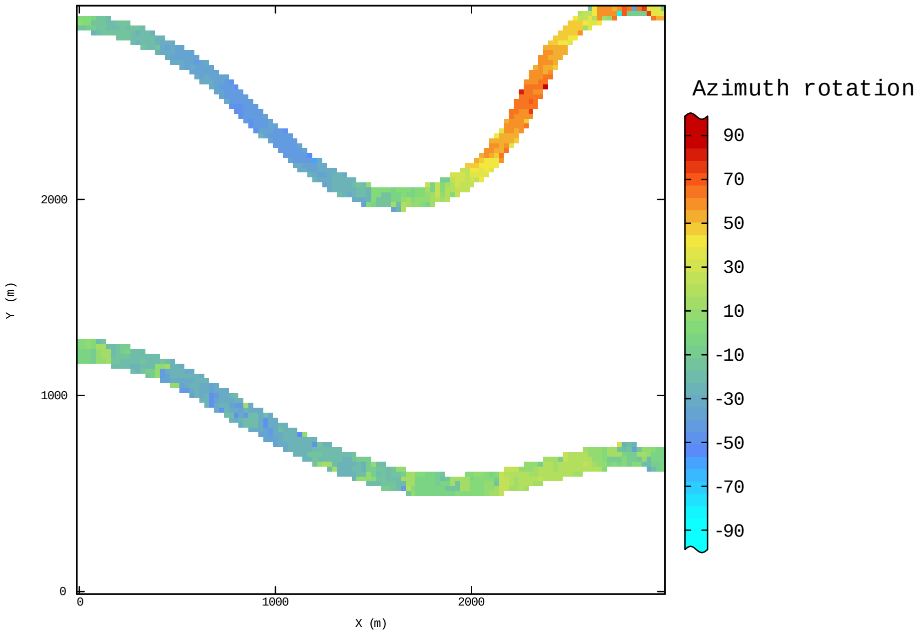

Figure 4: *Locally optimized parameter: azimuth rotation.*

Using the local azimuth rotation, Sequential Gaussian simulations (SGS) of porosity have been carried out within the channels. The local parameter reinforces the porosity continuity along the channels (see Figure 5 below) compared to a classical isotropic simulation.

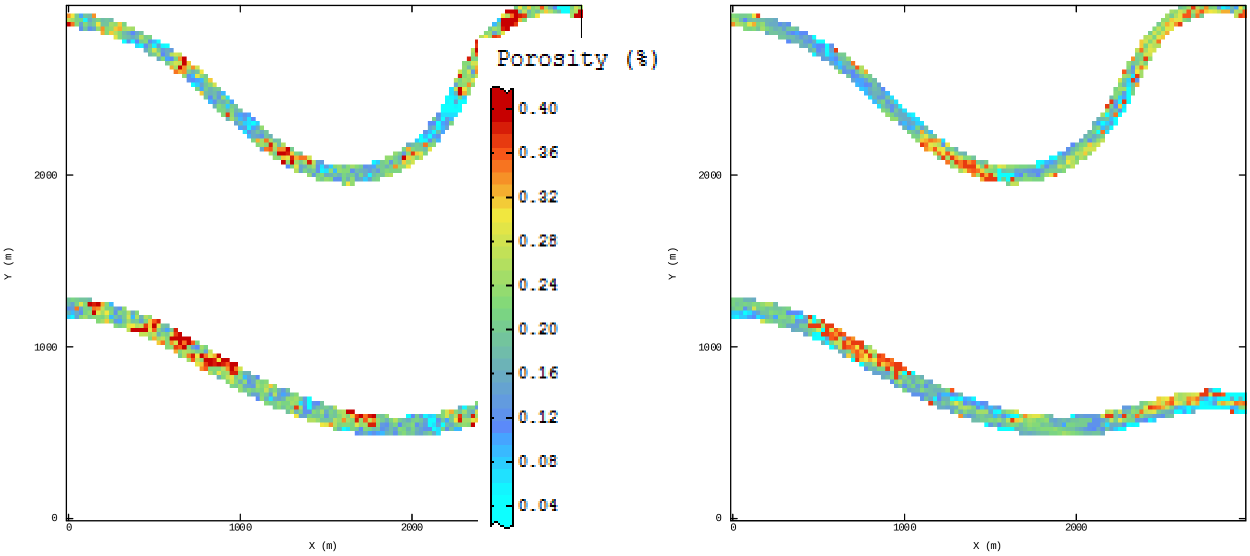

Figure 5: *A porosity simulation (left), a locally azimuth optimized porosity simulation (right).*

Conclusions

Combining various approaches in geomodelling (for facies or for petrophysical properties) can be interesting in order to get a more realistic and accurate reservoir model. In this paper, meandering channels simulations allowed to build a geologically realistic model. Geological information is then retrieved to run a lithofacies multiple-point simulation and a porosity modelling. To optimize the porosity modelling, local geostatistics are carried out. Such methods and procedures allow also reducing the uncertainties attached to the modelling.

Acknowledgements

All geostatistical computations are performed using Isatis© software (Geovariances, 2012).

References

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