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History Matching by Integrating Regional Multi-Property Image Perturbation Methods

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Introduction

Good reservoir characterization is essential to a successful exploitation strategy optimization, risk analysis and reliable production forecast. The high uncertainty in reservoir characterization is due to the difficulty to describe complex geological structures based on the lack of production data and well logs. Different reservoir properties, e.g. facies, porosity, net-to-gross ratio and permeability, have different impacts in reservoir production. This influence must be measured and, if necessary, the uncertainty reduced for that property. There are different ways to reduce uncertainty in petrophysical characterization. This work presents a consistent methodology that sequentially reduces image uncertainty using Probability Perturbation Method and Co-Simulation. In order to understand how the reservoir must be perturbed a multivariate sensitivity analysis was developed for petrophysical properties.

Methodology

The contribution of this work is focused in steps 10 to 12 from the methodology proposed in **Avansi *et al.*** (2016), for history matching and uncertainty reduction.

Firstly, it is necessary to choose the objective function to match and make a diagnostic of the best procedure to apply. Usually, two problems may occur: a) there is a large variability and uncertainty must be reduced or b) there are no fitted models to history data and a re-characterization is necessary.

The multivariate sensitivity analysis (SA) for petrophysical characterization is used to understand which property and location is crucial to match an objective function. By identifying the property is possible to locally reduce uncertainty or change the current characterization to improve the fit between production and history data.

Firstly, the reservoir must be divided into different regions. Voronoi is a simple and efficient approach. Secondly, by selecting a reservoir model as reference and applying regional multipliers in each property (porosity and permeability) it is possible to create a set of models that will give different production data (Figure1).

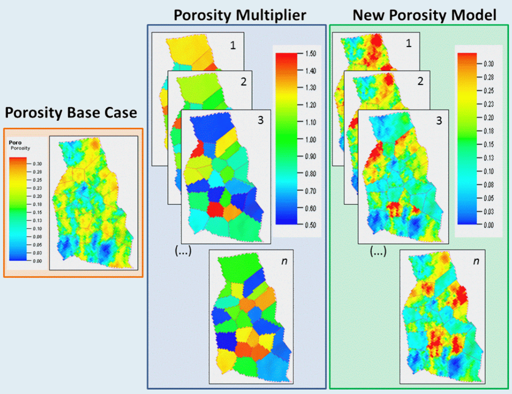

Figure 1: *Example of porosity models created for SA.*

After creating the models we simulate them and calculate the correlation between the variation of the attribute for each region and the variation in the NQDS value. This correlation can be described by a correlation coefficient or represented by plot containing in the X axis, the value for the attribute multiplier, and in the Y axis the value of NQDS, as illustrated in Figure 2.

We use uncertainty reduction when the objective function varies considerably and at least one geostatistical realization (GR) matches the data. This GR has the characteristics that we want to reproduce in the following iterations to ensure the match of history data.

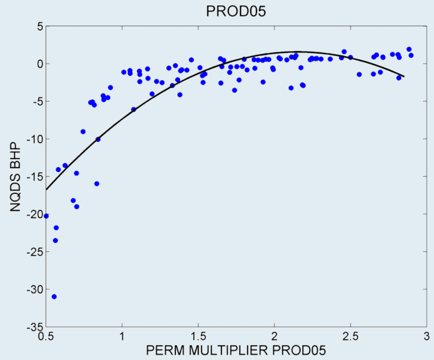

Figure 2: *Plot between attribute and NQDS.*

For this reason we use it as secondary information in image perturbation method, for categorical or continuous properties.

Figure 3 presents a particular case of uncertainty reduction in geostatistical realizations:

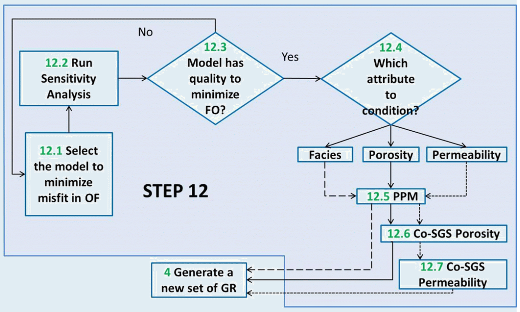

Figure 3: *Flowchart for uncertainty reduction in GR.*

- STEP 12.1: Choose a geostatistical realization that matches the objective functions. This image is used as a secondary variable in the Co-Simulation and Probability Perturbation Method.
- STEP 12.2: Perform the multivariate sensitivity analysis for petrophysical properties.
- STEP 12.3: Verify if the relationship between attribute variation and output respect the requisites to match the data.
- STEP 12.4: Identify which attribute is more influential in the history matching process and follow the flowchart properly.
- STEP 12.5: Perform the Probability Perturbation Method.
- STEP 12.6 and 12.7: Perform Collocated Co-Simulation.

With the parameterization and perturbation defined, a new set of geostatistical realizations can be generated.

On the other hand, re-characterizing a region may be necessary to improve the variability of an objective function. When no models cover the solution, it is possible to use Step 11 represented in Figure 4 and explained ahead.

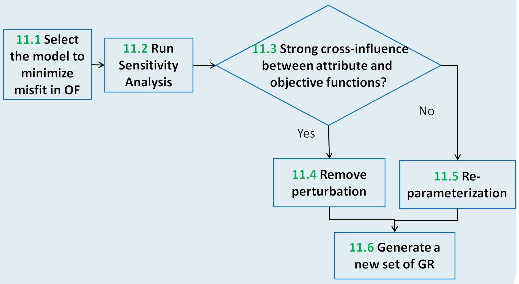

Figure 4: *Flowchart for characterization review.*

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- STEP 11.1: Selecting a base image.
- STEP 11.2: The multivariate sensitivity analysis is done in the same way as for uncertainty reduction.
- STEP 11.3: With the cross-plot describing the relationship between variation of attributes and NQDS value we can see how many regions and attributes affect an objective function. A high number suggests cross-influence and is preferable to remove the constraints to recover the prior probability and simultaneously do a Co-Simulation with the influential regions and attributes in the following iteration, matching well data in one step. However, if a single attribute in a fixed region is the main responsible for the mismatch, a re-parameterization can be done locally.
- STEP 11.4: Restore prior probability.
- STEP 11.5: The re-parameterization can take into account the cross-plot and the deviation needed for the base geostatistical realization chosen in step 11.1. Imposing a deviation means changing the local mean of the secondary image in the influential region using a multiplier. The best value to multiply is given by the cross-plot from the multivariate sensitivity analysis.

If permeability is an influential attribute, the spatial distribution of facies and porosity, that originated permeability image, should be kept, ensuring that porosity characteristics within each facies, and the relationship between permeability and porosity is respected. However, a key point of the proposed methodology is that if porosity is the influential attribute, instead of permeability, it is only necessary to condition facies and porosity, keeping the permeability uncertainty as high as possible, reducing the risk of constraining the solution too much.

Application and Results

To apply the proposed methodology we used the synthetic reservoir UNISIM-I-H (**Avansi and Schiozer, 2015**), which is a benchmark case for history matching and uncertainty reduction studies. The model has 14 production wells and 11 injection wells. It has 11 years of history data, where production wells have history data for the oil rate, water rate, liquid rate, and bottom-hole pressure, while injector wells have water injection rate and bottom-hole pressure.

We perturbed petrophysical properties sequentially. Facies and porosity were perturbed simultaneously through the target regions. This set of perturbation was called iteration "A" and had 8 loops, each loop generating a set of 150 reservoir images.

We then perturbed permeability to further reduce the uncertainty of the petrophysical property distribution. We did this in iteration "B" with 14 loops, again each loop generating 150 reservoir images. Through the application of the perturbation, we re-parameterized every time it was necessary. However, in many cases, it was done together with a Co-Simulation in other wells. The final iteration was "B14".

At the end of the process, the models generated were notably better matched than the initial set of models (Fig. 5 and Fig 6). More details can be found in Oliveira *et al.* (2017).

Conclusions

The regional multi-property image perturbation method has great advantage because it (1) allows us to perturb multiple and different types of petrophsyical properties, whether categorical or continuous, and (2)

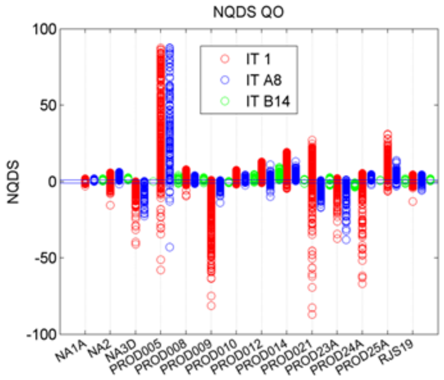

Figure 5: *NQDS for oil production.*

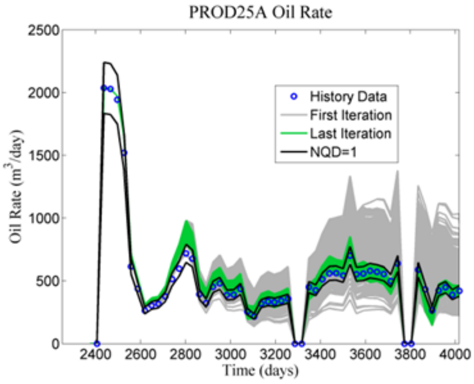

Figure 6: *Oil rate production for PROD25A in first and last iteration.*

improves the reliability of reservoir characterization, since the models generated simultaneously respect all well log data, variograms, geological knowledge and dynamic data.

The multivariate sensitivity analysis when used together with the perturbation method, greatly assisted the understanding of the relationship between the input and output of the model. It has been useful not only to identify influential attributes and regions but also to re-parameterize regions from mismatched wells and to understand the cross-influence between reservoir characterization and simulated data.

References

Avansi, D., Schiozer, D., 2015, "A New Approach to History Matching Using Reservoir Characterization and Reservoir Simulation Integrated Studies", Offshore Technology Conference, OTC-26038-MS.

Avansi, G. D.; Maschio, C.; Schiozer, D. J. "Simultaneous History Matching Approach Using Reservoir-Characterization and Reservoir Simulation Studies", SPE Reservoir Evaluation & Engineering, v. 19, pp. 694-712, November, 2016 http://dx.doi.org/10.2118/179740-PA.

Oliveira, G.; Schiozer, D.; Maschio, C. "History Matching by Integrating Regional Multi-Property Image Perturbation Methods with Multivariate Sensitivity Analysis", JPSE, v 153, pp. 111-122, May, 2017 http://dx.doi.org/10.1016/j.petrol.2017.03.031.

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