C06

The History Matching Problem with Geostatistical Priors in a Smooth Formulation

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SUMMARY

We focus on minimizing the number of reservoir simulation runs and conserving geological realism of the solutions when solving the history matching problem. Geological a priori information is taken into account by means of multiple point statistics borrowed from training images (conceptual geological models). Then production data and prior information are integrated into a single differentiable objective function, minimizer of which has a high posterior value. Solving the proposed optimization problem for an ensemble of different starting models, we obtain a set of solutions honoring both data and prior information.

Introduction

The history matching problem is often formulated as an inverse problem, where rock properties are needed to be estimated (inverted) from a production response. The history matching problem is known to be an extremely underdetermined. Therefore without geological constraints (complex a priori information) solutions of the history matching problem might be of a little practical use.

The inverse problem theory (Tarantola 2005) tells us to describe solution by its a posteriori density function (PDF). While Monte-Carlo simulation (Mosegaard and Tarantola 1995) seems to be an ideal tool for sampling the a posteriori PDF that integrates complex a priori knowledge (geological expertise) and the data, it is computationally unaffordable technique for the history matching problem.

Instead, one may be interested in finding a set of solutions that honour dynamic response and geological information. In closed loop optimization the history matching problem is needed to be solved fast, therefore methods based on gradient optimization may be sought-after. In our approach we focus on minimizing the number of reservoir simulation runs and conserving geological realism of the solutions. Geological a priori information is taken into account by means of multiple point statistics borrowed from training images (conceptual geological models). Then production data and prior information are integrated into a single differentiable objective function, minimizer of which has a high posterior value. Solving the proposed optimization problem for an ensemble of different starting models, we obtain a set of solutions honoring both data and prior information.

Methodology

We suggest a probabilistic formulation of the inverse problem that integrates data and a priori information into a single differentiable objective function, minimizer of which has a high posterior value:

$$\mathbf{m}^{HighPosterior} = \underset{\mathbf{m}}{\operatorname{argmin}} \left\{ \frac{1}{2} \|\mathbf{d}^{obs} - g(\mathbf{m})\|_{C_D}^2 + f^d(\mathbf{m}, \mathbf{TI}) \right\} \quad (1)$$

First term represents the data misfit. Second term is the misfit with the training-image based a priori information. Specifically, the term represents distance measure between multiple point statistics of the training image and the model defined in a smooth sense (Melnikova et al. 2013).

The smooth formulation allows applying gradient based optimization for solving the history matching problem. We demonstrate the method on a synthetic reservoir model, where the permeability field is sought to be reconstructed.

Conclusions

The suggested formulation has several advantages: 1) it guarantees prior-consistent solutions by including complex a priori information, 2) it allows using gradient-based optimization techniques, which save computational time, 3) it provides quantitative estimates of the data and prior information misfits and therefore allows us to distinguish between solutions as well as to choose the most reliable ones.

References

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