Interactive Visualization and Analysis of Optimization Algorithms and Large Parameter Spaces for Reservoir Geoscience and Engineering

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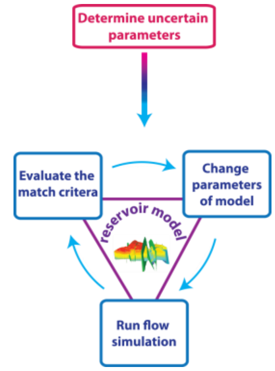
Summary

In this work we present novel techniques to support the understanding of multidimensional reservoir geoscience and engineering datasets, more specifically applied to history matching data. History matching is an inverse problem that attempts to tune parameters of a reservoir model in such a way that simulated data matches observed data. However, the solution of this problem is non-unique, i.e., multiple parameter combinations can lead to equally good matches. This work presents techniques that allow the engineers to analyze and compare different possible models and help the asset teams in decision making.

Introduction

Identifying specific processes relevant to particular reservoir phenomena is often difficult due to the complex interactions between reservoir features and properties, and the increasing size and complexity of reservoir models and related datasets. Existing methods for exploring time-varying reservoir data are usually based on time-step animations or arrays of static images [1]. These techniques are not effective for finding and classifying important temporal trends and/or activities in the reservoir production mechanisms. They provide an overview of the reservoir simulation model, which lacks the quantitative description of the evolving phenomena, the speed and time duration, connections or correlations with other features and data modalities (e.g. assigned/calculated data, graphs/plots, and tables) [2]. Methods need to be developed that support the visual exploration and analysis of reservoir data at different spatio-temporal resolutions. This would facilitate the user directly interacting with the data, discovering patterns and highlighting features based on time-varying trends [3], performing data correlation studies [4], detecting and verifying uncertainties [5], and creating meaningful and expressive semantic/query-based visualizations [6]. Visualization techniques operating within this exploratory analysis framework will allow the user cohesive insights and will yield scientific and engineering breakthroughs with reservoir datasets.



History Matching

A major problem in reservoir engineering is the development of reservoir models that reflect, as much as possible, the true characterization of the reservoirs. As it is not possible to perform a direct measurement of the rock properties over the entire reservoir extensions, history matching comes as an alternative to estimate such properties. History matching is a process where the reservoir simulation model is conditioned to the available field data. It aims to tune the model in order to be consistent with the field performance. A simulation model that can capture the past life of a reservoir is more likely to make accurate predictions.

Population-based Algorithms

History matching is modelled as a minimization problem, where the function to be minimized is the one that describes the difference between simulated and observed data. In Any optimization technique may be employed to solve the history matching problem. However, history matching does not present a unique solution, i.e., reservoir models with different properties may provide equally good matching, but their performance in predicting the future reservoir behaviour will be different. It is important for engineers to be provided with as much different possible models as possible, so they can analyse and decided which one(s) is(are) to be used in the process of decision-making.

Population-based optimization algorithms have recently enjoyed growing popularity for tackling history matching problem. These techniques work with multiple possible solutions per iteration and are known for exploring different regions of the parameter space at once. This makes these techniques very suitable for locating different possible parameter configurations.

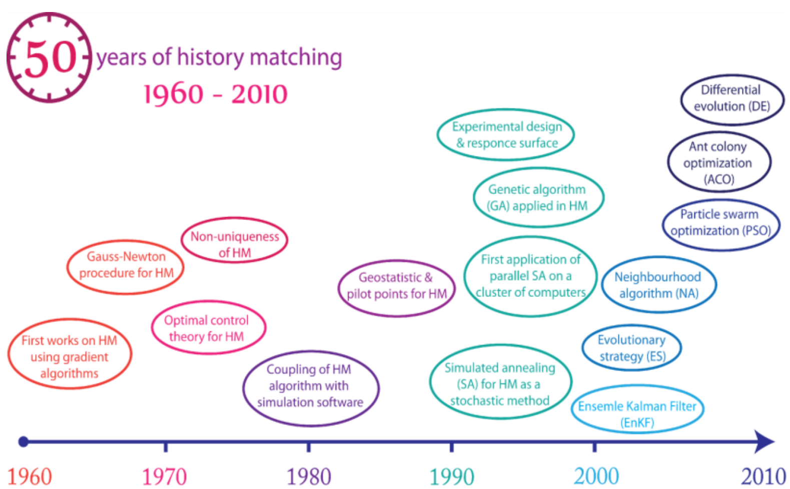


Figure 1 – Optimization techniques applied in history matching throughout the decades

Multidimensional Data

A single feasible solution for the history matching problem can be seen as a high dimensional vector, each dimension corresponding to one parameter to be estimated. Thus, the set formed by the multiple possible solutions is a multidimensional dataset. It is a challenge to visualize and compare the instances of a high-dimensional dataset, as conventional plotting is not able to capture all the dimensions at once. Recently one has observed the advent of numerous visualization techniques that aims on aiding one to make sense of high-dimensional datasets and extract information otherwise hidden. Each one of the existing techniques has their particularities that make them more or less suitable for a specific application. In this work we explore the powerfulness of *projection* techniques to visualize history matching data as a post-processing step; we also present *BubbleVis*, a novel approach to visualize and assisted the history matching process.

Goals

The main objective of this project is to conduct R&D on novel visual analytics tools and solutions to support uncertainty quantification for automatic and assisted history matching and oil field optimization. Comparison of multiple runs produced from history matching and visualization of simulations will allow the user to maximize the available information and facilitate decision-making. This project will serve as a basis for a more generic framework for the large number of opportunities for optimization during field development cycle (with or without historical data). This project will focus on history matching; however, oil and gas fields must be optimized and all of them have different levels and requirements for uncertainty quantification and visualization.

This project has two main deliverables: (1) Interactive Visualization and Analysis of Optimization Algorithms for Assisted History Matching and (2) Interactive Exploration of Large Reservoir Simulation Parameter Spaces.

Visualization and Analysis of Optimization Algorithms

Multidimensional projection techniques reduce the dimensionality of a dataset in such way the distances in the original space are preserved in the low-dimensional space. They are powerful methods as they allow visualizing a high-dimensional dataset in a 2D screen and understanding the relationship between different instances.

In this work we applied projection techniques to understand how different optimization algorithms explored the parameter space in a history matching problem. Figure 3 illustrates the space exploration for 5 different optimization techniques using a projection method called Least Square Projection [7].

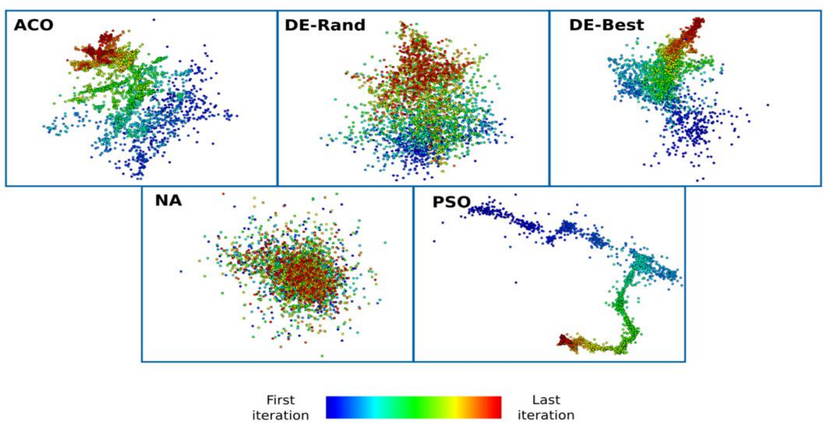


Figure 2 – LSP projection technique to visualize sampling performance of different algorithms

Interactive Exploration of History Matching Data

BubbleVis is a novel visualization approach to understand high-dimensional datasets. It associates each parameter with a bubble shaped element. The size of each bubble corresponds to the parameter value and the color encodes the fitness value of that specific parameter set. Bubbles of the same parameter set are displayed side by side, and different realizations are positioned in different horizontal lines. This visualization is coupled with optimization techniques and allows the user to add its domain knowledge to the iterative loop. The expert can include its input by selecting samples that he/she thinks are good, making the algorithm to give preference to that specific region(s) of interest. This is an approach to couple automatic and assisted history matching.

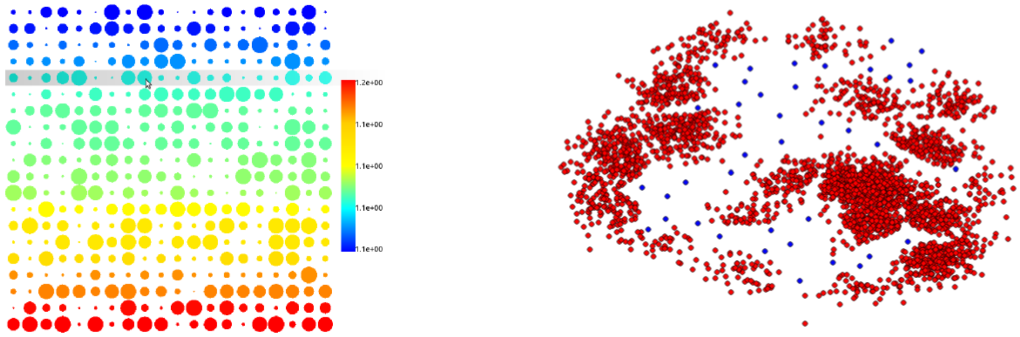


Figure 3 - BubbleVis (left) and iLAMP

iLAMP is a technique developed to perform what we call “backwards projection”. Given the 2D projection of a multidimensional dataset, the user may select points or regions in the 2D screen to be mapped back to the original space, creating totally new samples. iLAMP allows the user to not only analyze data in a post-processing step but to create new samples in regions that were revealed to be not well explored by the algorithm or sampling technique.

Acknowledgements

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