Modified Stochastic Inversion (MSI)

Anastasya Teitel (1), Anat Canning (1), Dominique Mouliere (1), Yuval Weiss (1), Matthew Goldman (1)
1. *Emerson (Paradigm)*

Summary

Stochastic inversion is a geostatistical technique for inverting seismic data into rock properties while incorporating uncertainty estimation and high-resolution results. It is used to explore geological features that are beyond the resolution of seismic data. The traditional stochastic process generates multiple equiprobable realizations that all match the seismic data. Analysis of the multiple outputs enables the evaluation of uncertainties about the presence of various geological features, their location and connectivity. Classic stochastic inversion is a very expensive process in terms of computational time. As a result, only a few realizations are usually generated, which may affect risk assessment.

This paper presents a Modified Stochastic Inversion (MSI), that provides greatly improved performance as well as higher result quality.

Introduction

Stochastic inversion is a technology that delivers real value for Quantitative Interpretation. The stochastic approach to seismic inversion provides not only rock property estimation derived from seismic data, but also statistics and uncertainty estimation of the results. In addition, stochastic inversion links well and seismic data, resulting in a broad-band image of the subsurface rocks. The output from stochastic inversion is a set of high-resolution multiple realizations of subsurface properties, all matching the seismic data. The multi-realization output scheme is what enables the estimation of uncertainly.

The match to the seismic data is achieved by minimizing the difference between the real seismic trace and a synthetic trace computed from estimated impedance. The impedance trace that provides the best match on the seismic trace level is selected to be the final output of inversion. This "matching" procedure is indifferent to the well data and is therefore limited to the seismic frequency band.

This paper proposes a new method for performing stochastic inversion, through integration of the deterministic inversion and stochastic process. Let us first review the main differences between these two inversion techniques: Deterministic inversion produces the "match" to seismic data using standard optimization methods, such as conjugate gradient. Low frequencies are normally introduced by a "background model", which is some combination of well log interpolations (Kriging) and seismic velocities (Co-Kriging). Deterministic inversion is limited in high-frequency bands to the seismic bandwidth. Stochastic inversion is an extension of the SGS (Sequential Gaussian Simulation) approach used to match the result with the seismic data. It provides multiple realizations of broad-band impedances. The process of matching to seismic data is in fact filtering of the low and high frequencies, while matching is done only within the seismic frequency bandwidth. Therefore, the final broad-band output is affected in the low and high frequencies by well data only.

Methodology

MSI is a prestack stochastic inversion that is based on the fact that well data and seismic data contribute to the final result in separate frequency bands. The classic stochastic inversion, which attempts to solve the full frequency range in a single process, is not only very expensive, but is also suboptimal for each spectral band.

The main idea behind MSI is to separate the procedure into three frequency bands: low, medium and high. In each frequency band a separate procedure is performed, and the final result is spectrally merged. For the central frequency range, a deterministic inversion is used. It is easy to show that this is equivalent to what classic stochastic inversion does within the seismic bandwidth. Figure 1 compares the effects from deterministic vs. MSI inversions within the seismic frequency band by comparing real seismic to the synthetic data created from the two types of inversion. One can see that they are very similar.

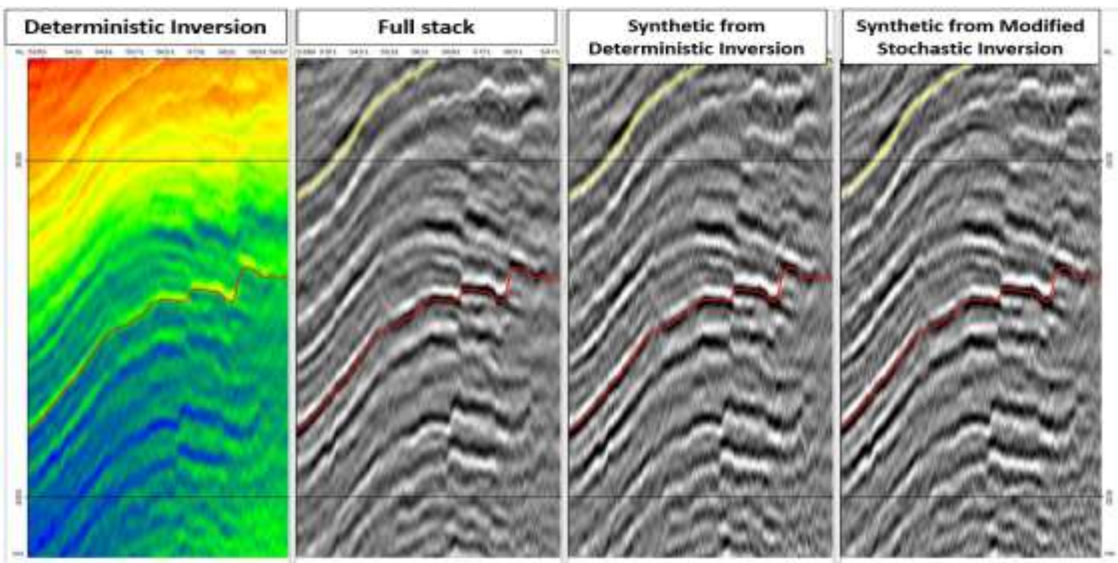

Figure 1: Comparison of deterministic vs. MSI inversion effects within the seismic frequency band.

There are many benefits to this approach. Firstly, it is very fast and therefore enables the generation of many iterations, improving statistics and uncertainty estimation. In addition, optimal procedures for each frequency band are performed. A choice of deterministic inversion algorithm is important factor in the process, delivering improved results in the seismic frequency band. Low frequencies are performed with co-kriging or co-SGS of well data using filters, variograms and co-datasets which best encapsulate the low-frequency components. The high frequencies are captured with co-SGS of well data using filters, variograms and co-datasets which best encapsulate the high-frequency components.

The final result is created using spectral merge. The choice of the merging parameters should be carefully selected. Figure 2 illustrates the process showing the deterministic inversion and the SGS separately, and the final MSI result.

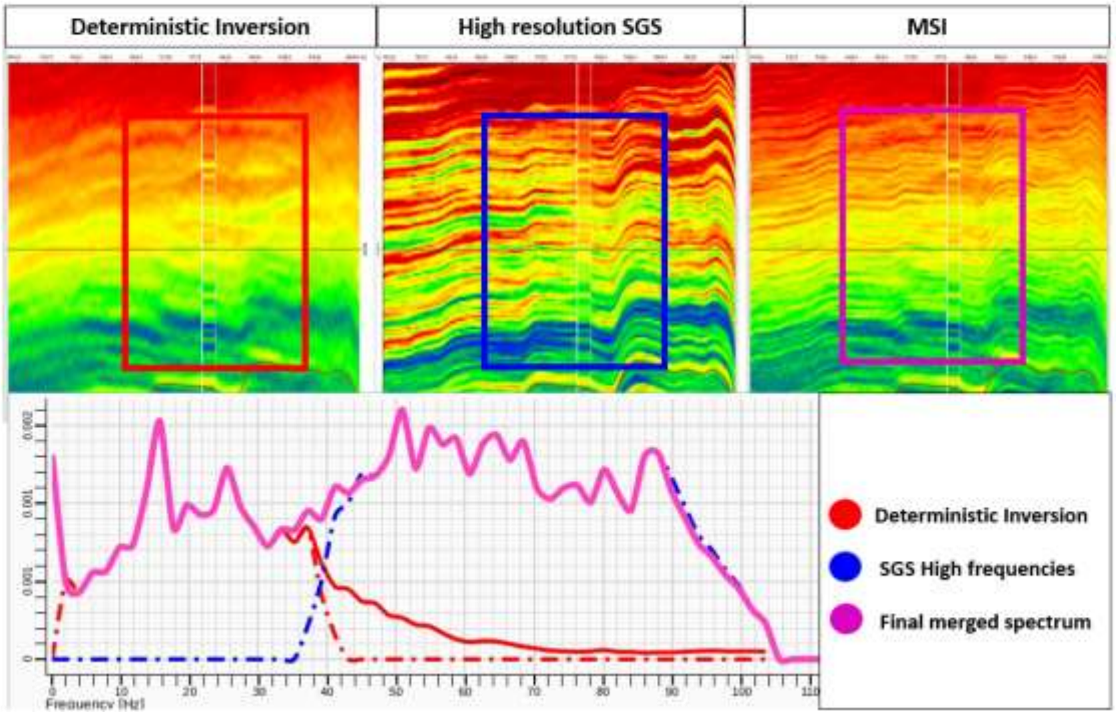

Figure 2: Example using a dataset from the East Mediterranean basin. Left – deterministic inversion result; center - Co-SGS; right - full MSI. The frequency spectrum presented at the bottom shows how different inputs contribute to the MSI result.

Conclusions

MSI is an alternative approach to Stochastic Inversion. It provides equiprobable high-resolution outputs that all match the seismic data and tie to the wells. The presented method is unique in its concept; it significantly accelerates the process while providing flexibility and optimization for best results.

Acknowledgements

We would like to thank GALP Energia, who sponsored this project and helped to turn the idea of MSI into a reality.

In addition, we would like to acknowledge the Israeli Ministry of Energy and Water Resources for permission to use seismic and well data in this paper.