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Modern resource modelling with quantitative geological constraints

Vargas-Guzman, J.A.[1]

[1]Saudi Aramco, EXPEC-II, 5140, Dhahran, 31311, KSA.

This study is motivated by the impact of correlations among rock properties and structural elements, in the regionalized forecast of resources. For example, the thickness of cells is usually segmented from coarser separation between horizon boundary surfaces, and cells are classified by predicted facies; from which two major issues arise. First, the cross-correlation between fine scale geometrical structural features (e.g., cross-bedding, gradations, pinch-outs, fracture apertures, etc.) and petrophysical properties in resource models must match measured parameters from hard data. Second, the anisotropic heterogeneity at fine scale cannot be ignored to jointly predict the correlated geometry of elements, porosity, permeability, and fluid saturations. Furthermore, the problem becomes complicated if more than two properties for resource computations are predicted [1]. For instance, fluid saturation forecasted conditionally to porosity and structural high-resolution thickness requires a third-order cross-correlation, in addition to cross-covariances. These claims are derived via perturbation analysis, and tested with abundant data.

A new leap for resource modelling technology is to achieve models with geocellular elements, matching realistic geometrical heterogeneity that allows handling structural uncertainty, while serving as quantitative constraints in posterior rock property models. Before one can make such models with cross-correlations between fine structural elements and rock properties, the practitioner must have a suitable algorithm to predict structural features, matching the desired variable anisotropy [2] from hard data. Second, the approach must handle multivariate forecasts. In consequence, this study yielded a new form of kriging, termed functional kriging.

Functional kriging allows the prediction of the probability of rock occurrences and their gradients by modelling uncertain structural anisotropy tensors and nonstationary phenomena. In consequence, discrete and continuous property models with curved patterns (e.g., meandering and braiding channels, sinuous sequences, and folded structures) can match measured structural anisotropy vector data. Embedding anisotropy fields into geostatistical modelling through spatially variable covariance functions or higher-order structures is a desirable option that includes quantitative structural geological constraints from measured anisotropy into regionalized models.

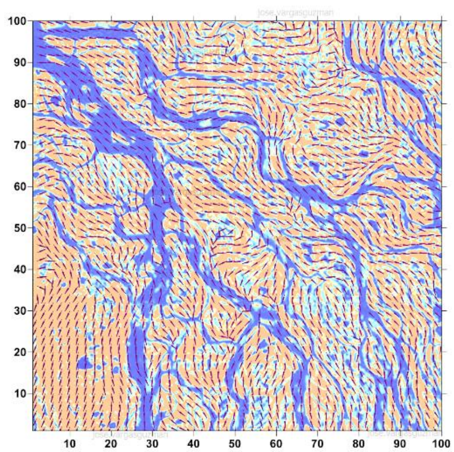

Figure 1: Anisotropy Vector Field (2D - East, North, km) Example from Functional Kriging

Continuous Hilbert space functionals are constructed with spatially variable anisotropy parameters. The estimation approach yields continuous forecasting functions for uncertain anisotropy non-orthogonal vectors, at non-sampled locations. Consecutive projections allow for simulated realizations, which are the summation of component layers. Figure 1 is an example for an anisotropy vector field based on only 400 anisotropy data samples. In addition, spatial stochastic integration of estimated functions delivers multi-resolution models, for variable size and shape of block elements. Since functional kriging can be stopped, optimized and updated without repeating all the computations, it is suitable for inverse, adaptive, and real-time modelling.

References:

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