Interpolating Assays and Physical Properties in Folded and Faulted Layered Geology

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The GeoModeller Domain kriging algorithms, Guillen et al, 2011, implement two new methods for interpolating petrophysical properties (porosity, permeability, density, magnetic susceptibility) or chemical grades (Fe, Cu, Pb, Zn…) while honouring the geometry and internal structure of the host geological units.

Traditional distance weighting interpolation methods that calculate the distance between samples using Cartesian coordinates (east, north and elevation) are not satisfactory in a folded and faulted stratigraphic unit or banded ore horizon. The distance between samples is no longer a straight line, Figure 1, Guillen et al, 2011. Current methods used to solve this problem involve unfolding prior to interpolation followed by reconstruction back to the original geometry. This can be a very difficult process in complex structural environments.

The GeoModeller Domain Kriging algorithms are described below, Guillen et al, 2011.

1. When the variability of the parameter to study is mainly correlated with the pot coordinate (a metal deposited by a sedimentary process), the variogram in the space (pot, dg, θ) is in reality a function of pot and we have:

   $\gamma(pot,dg,\theta) = \gamma(pot)$

   In this case, we have pure "zonal anisotropy"

   The normal coordinate to the isovalues, Figure 1, defines the potential coordinate (pot); it represents the value of the potential field function. Computation of potential distance (orthogonal to potential isovalues) between the two points A and B, pot (A, B) is very easy: it is the absolute value of the difference between pot (A) and pot (B). This can be thought of as a measure of formation thickness between points A and B.

   This algorithm is fast to compute due to its relative simplicity.

2. The General case: $\gamma(pot,dg,\theta) = \gamma(pot,dg_u,dg_v)$

   Where:

   - dg_u, dg_v represent respectively the geodesic distances along the u axis and the v axis, which are the axes representing the anisotropy in the xy plane.
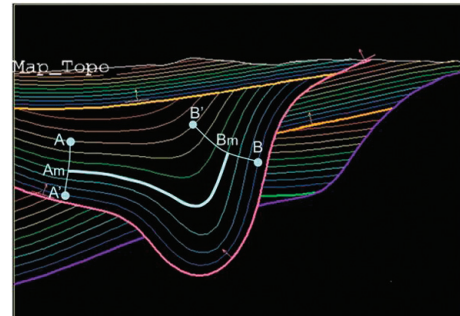

Figure 1: Curvilinear distance between two points A and B: Point A is on the isovalue potA, point B is the isovalue potB. The distance dg (A, B) is the length of the arc AmBm (in blue) at isovalue potM = (potA + potB)/2. The distance dg (A, B) is therefore defined as dg (Am, Bm).

- dg_u and dg_v are the projection on the principal axes u and v of the geodesic distance dg and u and v are the directions of anisotropy on the plane xy rotated with an angle θ from axis x and y.

We may have a geometric anisotropy on the plane xy and zonal anisotropy along the pot coordinates and two different nugget effects for pot coordinate (C_0^{pot}) and xy plane (C_0^{dg}).

Further work is required to improve the performance of this second domain Kriging algorithm in GeoModeller as it is computationally heavy.

Data Import Storage, Validation and Kriging Procedures in GeoModeller

GeoModeller allows the user to load 3D numeric drillhole data as from/to intervals attached to 3D drillhole desurveyed path objects where they can be viewed and compared with logged geology and the interpolated geology model computed by the dual co-kriging method, Lajaunie et al. 1997.

A procedure to regularize (composite) irregular from/to sample intervals is available and should be used. Regularised drillhole numeric data is then transferred to a 3D vertex mesh for statistical/neighbourhood/variogram analysis and

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interpolation. Alternatively 3D numeric point data derived from sources other than drillholes may be loaded directly into a GeoModeller 3D vertex mesh for analysis (surface and underground sampling, seismic velocity …).

Geostatistical procedures follow the normal sequence of variogram analysis and cross validation followed by interpolation using the chosen Kriging method (1D, 2D, Domain Pot, Domain uvPot) or Sequential Gaussian simulation. An Inverse distance interpolator is also available.

The Domain Kriging algorithms, by following the geology gradients, produce a tighter more natural distribution of interpolated physical values.

Examples of the Application of Domain Kriging

A folded and faulted resource example is presented to demonstrate the improvements that the new Domain kriging algorithms can make to more traditional classical Kriging interpolation results in this environment.

The Domain Kriging method has also been used in the interpolation of physical properties (density and susceptibility) where the explorer wishes to determine whether his drilled resource target fully explains the observed geophysics (gravity and magnetic surveys). The interpolated physical property 3D grids or voxets are used as inputs to GeoModeller's geophysical forward modeling and stochastic inversion. This is considered to be a more robust alternative to single property modeling of the resource geology. An ability to estimate geological uncertainty at all points in the 3D resource model is an extra independent capability of these techniques.

Acknowledgements

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