Mapping with Auxiliary Data of Varying Accuracy

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Introduction

There are several ways for integrating different sources of data in mapping processes:

- Multivariate estimations (cokriging, collocated cokriging) which require the fitting of a multivariate model (variograms and cross-variograms) and a stationary context;
- Kriging with external drift or kriging with Bayesian drift, which can be applied in non-stationary contexts and require a univariate model.

These methods require a sufficient amount of data, well distributed in space. If not, an alternative approach consists in using additional soft data (with attached uncertainty) in empty zones. Dummy data correspond to the studied variable. It only requires a univariate model.

→ **Use of datasets of different accuracy on the same variable is an efficient method for improving mapping results**

Example 1: Extrapolation control

Issue: Lack of data leads to unrealistic extrapolation results and kriging artefacts

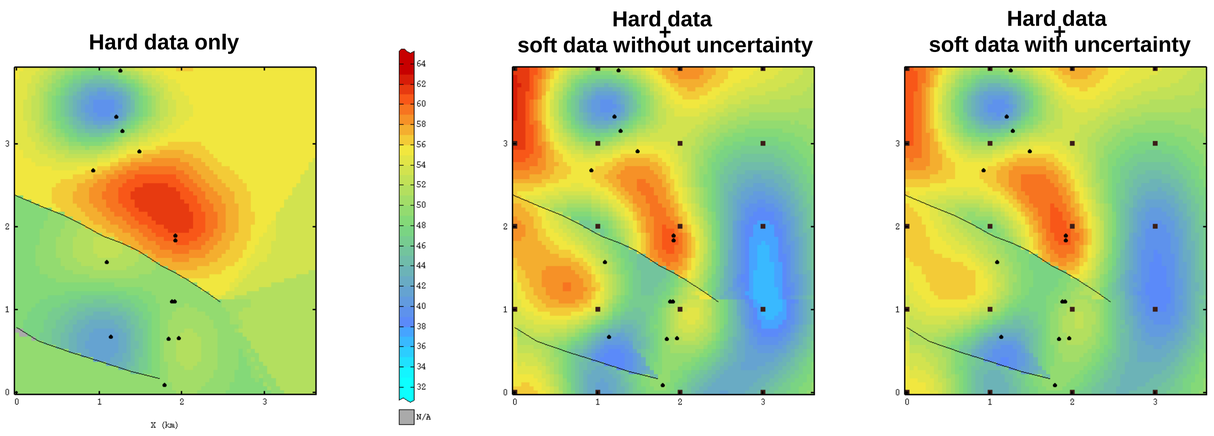
Solution: Add soft data points

- Dummy data points can be added, with a user defined uncertainty attached to each point
- Soft data points correspond to the studied variable ⇒ univariate model
- Kriging with measurement error is used

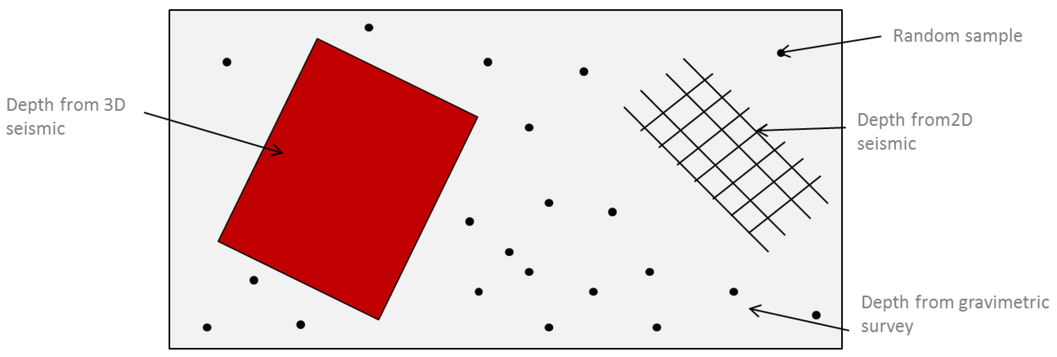
Result: User controlled extrapolation

- Soft data distribution, values and attached uncertainty are defined by the geologist
- Kriging artefacts are significantly reduced
- Weaker hypothesis than adding dummy data considered as hard data

→ **Useful method when trend maps or correlated auxiliary variables maps are missing**



Example 3: Horizon mapping mixing data sources



Issue: Mixing data sources of different resolution

- In the example, different geophysical data sources are available, but few wells
- Using few hard data with several auxiliary collocated variables leads to artefacts
- Depth maps deduced from each single data source are of different accuracy

Solution: Auxiliary source maps sampling + Kriging with measurement error

- To compensate for the lack of hard data, auxiliary depth maps calculated from each geophysical data source can be sampled, a variance being attached to each sample
- The variance attached to each sample depends on the data sources resolution and reflects the uncertainty
- Available well data (no uncertainty) plus additional samples (with uncertainty attached) are merged to estimate depth by kriging with the « measurement error »

Result: Consistent maps taking benefit of all data sources

Accounting for data uncertainty and data value range

Kriging with measurement error

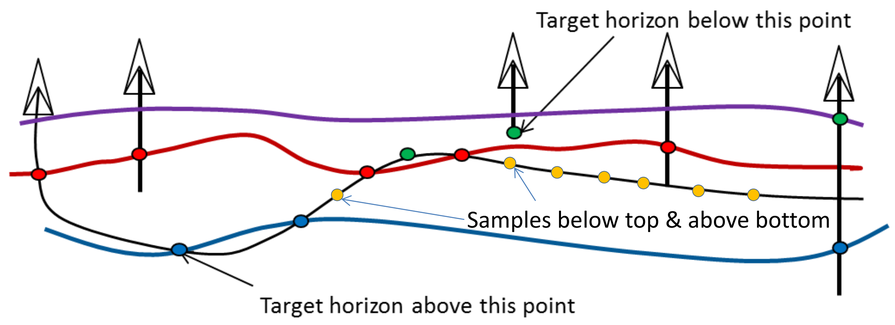
- Varying nugget effect added to the Variance-Covariance Matrix diagonal
- Kriging weights account for data uncertainty, more weight being given to certain data

Conditional Expectation with inequalities

- Uses hard data and soft data defined by intervals of values
- Conditional simulations are run, using hard data and simulated values in intervals at soft data
  - Provides Conditional Expectation and standard deviation
  - Univariate model

→ **The two methods accounting for uncertain data can be linked in efficient workflows**

Example 2: Horizon mapping using horizontal wells



Issue: Optimizing the use of horizontal well traces for mapping horizons

Solution: Define inequalities

- Intercepts between horizontal well trace and horizons are hard data
- Other well trace points are above or below horizons and used in the Conditional Expectation with inequalities algorithm
- Conditional Expectation results are then used as soft data in kriging with measurement error, with an attached uncertainty

Result: Enhanced maps of layer limits

- Maximizes the value of the whole information available
- Kriging weights assigned to each data point account for its uncertainty

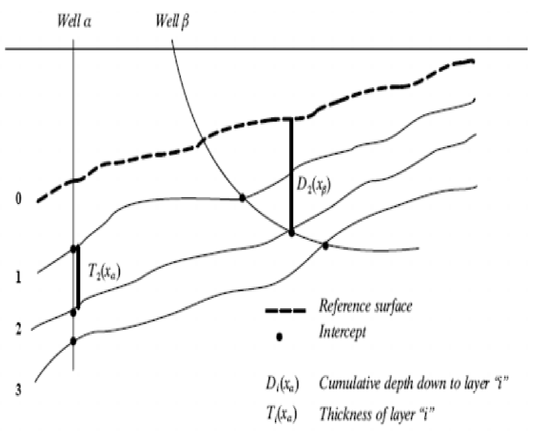
Example 4: Horizon mapping in layer-cake models

Issue: Mapping intermediate layer limits in a geological model

Several sophisticated multivariate methods are available to solve this problem. What can be done if these methods cannot be applied (lack of data, stationarity,…)?

Solution: Use each layer as an inequality

- Each already calculated top layer map can be used as a maximum for the next top layer just below
- The geologist can optionally determine a minimum for the next layer by adding maximum local thickness map
- Sample the extreme maps and use the Conditional Expectation with inequalities algorithm, which results will be used in kriging with measurement error, combined with wells intercepts



Result: Consistent maps taking benefit of all data sources

- A geometrically consistent set of maps is obtained, each map being used to calculate the next one
- Undesired crossing between layer tops are well controlled and limited
- A simple univariate model is required for each map

Conclusions

- Combining **Conditional Expectation with Inequalities** and **Kriging with measurement error** in workflows allows enhancing mapping results and better controlling the shape of the maps .
- It is a univariate approach which is easier to implement than multivariate methods. It also allows accounting for the Geologist's or Geophysicist's empirical knowledge.
- These methods lead to a an uncertainty reduction

All results obtained using isatis software, developed by Geovariances. For more information: http://www.geovariances.com