Geostatistical regularization methods for synthetic ERT crosshole imagery

Konstantinos Tsakirmpaloglou[1], Olivier Kaufmann[1]
(1) University of Mons, Belgium
Keywords: geostatistical regularization, crosshole imagery, smoothing constraints

Electrical resistivity tomography (ERT) is used for imaging and monitoring method with plenty of applications in geology, hydrogeology, environmental investigations hydrogeophysics, etc. A special implementation of ERT is crosshole ERT where electrodes are in boreholes. Although it requires greater effort, this setting allows for better resolution at depth and long-term monitoring even where surface electrodes cannot be left in place at the ground surface.

The most common imaging method in ERT is based on a formulation of the inverse problem as an optimization problem. Solving this ill-posed inverse problem depends on the minimization of a function (Φ) that is comprised by two terms. The first term corresponds to the misfit between the reconstructed model response and the observed data, while the second term, constrains for the uniqueness of the minimization problem.

With the classical regularization, the constraints in the second term are defined between a cell and adjacent cells. In contrast, the geostatistical operators consider expected correlations between reconstructed parameters in a wider neighbourhood around a particular cell. In slightly deformed stratified media, geostatistical regularization showed that it leads to geologically more realistic and accurate results than approaches based on classical smoothing constraints with anisotropy (Jordi et al., 2018). However, one of the main challenges is the determination of the correlation model to be used in the constraints. This correlation model could be derived from prior knowledge (e.g. local geological setting) or from observations and sampling conducted during the drilling of the boreholes.

To assess how the correlation model parameters could be derived from observations in the boreholes, we designed a set of synthetic cases. In these cases, the resistivity field is the realization of a geostatistical random function characterized by a known correlation function with geometric anisotropy. The random fields (synthetic reality) were then sampled along vertical lines representing boreholes. From the geostatistical analysis of these samples, a coarse model of the main directions and correlation lengths of the resistivities, represented by an ellipsoid, is derived. Using this information in the geostatistical constraints of the regularization term, we could obtain inverted sections that are closer to the synthetic reality than using classical smoothing constraints.

In a second step, alterations of the random field were made to simulate local changes in the resistivity field. These experiments reflect the dynamic nature of phenomena that could be monitored by crosshole long-term ERT monitoring systems.

Jordi, C., Doetsch, J., Günther, T., Schmelzbach, C., Robertsson, J. O. (2018): Geostatistical regularization operators for geophysical inverse problems on irregular meshes. *Geophysical Journal International*, *213*(2), 1374-1386, https://doi.org/10.1093/gji/ggy055.