Geoelectrical imaging of subsurface discontinuities and heterogeneities using low-dimensional parameterizations

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Geophysical imaging is subject to inherent non-uniqueness due to the ill-posed nature of the inverse problem. To mitigate this, the solution is commonly subjected to regularization. Smoothing regularization is widely used in practice, but produces high-dimensional images without sharp contrasts between geological units. These tomograms stand in contrast to current implicit geological models, which are able to produce sharp subsurface interfaces with complex geometries using low-dimensional parametrizations. This work aims to bring together modelling concepts from geophysics and geology using the example of electrical resistivity tomography (ERT).

An implicit geological model is used as the centerpiece of a 2D ERT inversion within a deterministic Gauss-Newton framework. The points that define the surfaces of the geological model are included into the model vector of the inverse problem along with a low-dimensional pilot point parametrization of the subsurface electrical resistivity. The point-based parameterization is translated to a triangular finite-element mesh to solve the geoelectrical forward problem. Sensitivities for the geological interfaces and resistivity parameters are efficiently calculated based on finite-differences and the reciprocity theorem, respectively. Each iteration step produces an update of both the geological interface as well as the parameter fields.

The approach converges to an updated geological model and a distribution of subsurface resistivity, which are in accordance with the measured data. The tomograms show sharply localized and realistic subsurface interfaces that are described by only a few parameters. While the imaging of small-scale heterogeneities is challenging and would require a locally increased number of pilot points, the current approach allows for the estimation of smoothly distributed heterogeneities. Further advantages of the approach lie in the improved integration of a-priori geological knowledge, the straightforward extension to 3D, and the applicability to other geophysical methods as well as joint inversion.