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Geophysical Inversion With Multi-Objective Global Optimization Methods

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We are investigating the use of Pareto multi-objective global optimization (PMOGO) methods to solve numerically complicated geophysical inverse problems. PMOGO methods can be applied to highly nonlinear inverse problems, to those where derivatives are discontinuous or simply not obtainable, and to those were multiple minima exist in the problem space. PMOGO methods generate a suite of solutions that minimize multiple objectives (e.g. data misfits and regularization terms) in a Pareto-optimal sense. This allows a more complete assessment of the possibilities and provides opportunities to calculate statistics regarding the likelihood of particular model features.

We are applying PMOGO methods to four classes of inverse problems. The first are discrete-body problems where the inversion determines values of several parameters that define the location, orientation, size and physical properties of an anomalous body represented by a simple shape, for example a sphere, ellipsoid, cylinder or cuboid. A PMOGO approach can determine not only the optimal shape parameters for the anomalous body but also the optimal shape itself. Furthermore, when one expects several anomalous bodies in the subsurface, a PMOGO inversion approach can determine an optimal number of parameterized bodies.

The second class of inverse problems are standard mesh-based problems where the physical property values in each cell are treated as continuous variables. The third class of problems are lithological inversions, which are also mesh-based but cells can only take discrete physical property values corresponding to known or assumed rock units.

In the fourth class, surface geometry inversions, we consider a fundamentally different type of problem in which a model comprises wireframe surfaces representing contacts between rock units. The physical properties of each rock unit remain fixed while the inversion controls the position of the contact surfaces via control nodes. Surface geometry inversion can be used to recover the unknown geometry of a target body or to investigate the viability of a proposed Earth model.

PMOGO methods can solve numerically complicated problems that could not be solved with standard descent-based local minimization methods. This includes three of the classes of inverse problems mentioned above. There are significant increases in the computational requirements when PMOGO methods are used but these can be ameliorated using strategies such as parallelization and problem dimension reduction.