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3D geophysical inversion for contact surfaces

Peter Lelièvre and Colin Farquharson
Memorial University of Newfoundland, Department of Earth Sciences, St. John's, NL, Canada

Geologists' interpretations about the Earth typically involve distinct rock units with contacts (interfaces) between them. In contrast, standard minimum-structure volumetric inversions (performed on meshes of space-filling cells) recover smooth models inconsistent with such interpretations. There are several approaches through which geophysical inversion can help recover models with the desired characteristics. Some authors have developed iterative strategies in which several volumetric inversions are performed with regularization parameters changing to achieve sharper interfaces at automatically determined locations. Another approach is to redesign the regularization to be consistent with the desired model characteristics, e.g. L1-like norms or compactness measures. A few researchers have taken approaches that limit the recovered values to lie within particular ranges, resulting in sharp discontinuities; these include binary inversion, level set methods and clustering strategies.

In most of the approaches mentioned above, the model parameterization considers the physical properties in each of the many space-filling cells within the volume of interest. The exception are level set methods, in which a higher dimensional function is parameterized and the contact surface is determined from the zero-level of that function. However, even level-set methods rely on an underlying volumetric mesh. We are researching a fundamentally different type of inversion that parameterizes the Earth in terms of the contact surfaces between rock units.

3D geological Earth models typically comprise wireframe surfaces of tessellated triangles or other polygonal planar facets. This wireframe representation allows for flexible and efficient generation of complicated geological structures. Therefore, a natural approach for representing a geophysical model in an inversion is to parameterize the wireframe contact surfaces as the coordinates of the nodes (facet vertices). The geological and geophysical models can be specified using the same parameterization: they are, in essence, the same Earth model. We solve for the locations of the nodes through a Particle Swarm Optimization strategy and follow this with a more rigorous stochastic sampling to provide likelihood information. Such global optimization methods introduce high computational costs; to provide computationally feasible inversion methods, we reduce the dimensionality of the problem by parameterizing the nodes in a coarse representation of the geological wireframe model and we use splines (2D) or surface subdivision (3D) to refine further. This also provides a simple and effective way to regularize the inverse problem.