Gradient and roughness regularization operators for geophysical inversion on unstructured meshes using ℓ_2 and ℓ_1 norms

M. Kangazian[1], C. Farquharson[1]
[1]Memorial University of Newfoundland, St. John's, NL, Canada, Department of Earth Sciences.
mkangazianka@mun.ca, cgfarquh@mun.ca

SUMMARY

Minimum-structure, or "Occam's", style of inversion requires proper regularization strategies to gain sensible geophysical models. Designing the spatial matrix operators required for the regularization term for unstructured meshes is not as straightforward as for structured meshes because of the complex geometric and spatial properties of unstructured meshes. Perhaps the simplest method of calculating the spatial gradient operators for unstructured tetrahedral meshes is the one that calculates the physical property differences across all internal mesh faces. However, this type of regularization is not able to incorporate structural orientation information such as strike, dip, and tilt angles into an inversion, which can be particularly important information for survey methods with limited depth resolution such as gravity and magnetics, as well as for electrical and electromagnetic methods such as magnetotellurics. Hence, other methods have been proposed for calculating the gradient operators for unstructured tetrahedral meshes that allow one to incorporate the structural orientation information of geological features into the inversion framework and obtain more sensible geophysical models.

The majority of these methods consider a cell along with the nearest neighbours of that particular cell as a package to prevent a patchwork pattern being created, and commonly an ℓ_2 norm is used for the measure of the regularization term. These methods work well and allow the orientation information of a geological structure to be incorporated into the inversion to give desirable methods. However, the models constructed using these regularization methods are not as sharp as hoped for when the regularization function uses ℓ_1-norm measures instead of an ℓ_2 norm due to the package issue.

In this study, the effect of the package issue is investigated for the scenarios in which an ℓ_1-norm measure is employed in the regularization term. Also, the method that calculates the gradient operators across the interior faces of the mesh is extended so that geological orientation information of a body can be incorporated into an inversion. It shall be shown that the models constructed by this method have sharper boundaries compared to the models constructed using methods that consider each cell as a package with its neighbours.

Keywords: Inversion, Regularization, Unstructured tetrahedral meshes