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A new co-operative inversion strategy via fuzzy clustering technique applied to seismic and magnetotelluric data

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Geophysical inversion produces very useful images of earth parameters; however, inversion results usually suffer from inherent non-uniqueness: many subsurface models with different structures and parameters can explain the measurements. To reduce the ambiguity, extra information about the earth's structure and physical properties is needed. This prior information can be extracted from geological principles, prior petrophysical information from well logs, and complementary information from other geophysical methods. Any technique used to constrain inversion should be able to integrate the prior information and to guide updating inversion process in terms of the geological model. In this research, we have adopted fuzzy c-means (FCM) clustering technique for this purpose. FCM is a clustering method that allows us to divide the model of physical parameters into a few clusters of representative values that also may relate to geological units based on the similarity of the geophysical properties. This exploits the fact that in many geological environments the earth is comprised of a few distinctive rock units with different physical properties. Therefore FCM can provide a platform to constrain geophysical inversion, and should tend to produce models that are geologically meaningful.

FCM was incorporated in both separate and co-operative inversion processing of seismic and magnetotelluric (MT) data with petrophysical constraints. Using petrophysical information through FCM assists the inversion to build a reliable earth model. In this algorithm, FCM plays a role of guider; it uses the prior information to drive the model update process, and also forming an earth model filled with rocks units rather than smooth transitions when the boundary is in doubt.

Where petrophysical information from well logs or core measurement is not locally available the cluster petrophysics may be solved for in inversion as well if some knowledge of how many distinctive geological exist. A better way to handle this limitation on prior petrophysical knowledge is to integrate complementary information of seismic reflection and MT data using a co-operative inversion process. This strategy can utilize the high resolution of seismic data to support low resolution of MT data and vice versa; the seismic reflection model, which lacks low frequency information, benefits from the general background produced by MT data. Hence, the most comprehensive process is to use co-operative inversion of seismic reflection and MT data constrained by petrophysics via FCM.

Using synthetic examples, we show that our methods can effectively recover the true earth models. Separate inversion of seismic and MT using FCM produces significantly better results than a conventional inversion process. The co-operative inversion of seismic and MT data demonstrate that seismic data increases the effective resolution of MT data and in turn seismic impedance models benefit from the lower frequency data in the MT model.

Key words: seismic inversion; magnetotelluric inversion; co-operative inversion; petrophysical constraint; fuzzy c-means