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A piecewise constant level set method for inversion of full magnetic gradient tensor data

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Inversion of magnetic gradient tensor data brings a new choice while there are still difficulties in potential field inversion paradigms. In order to obtain a unique and stable inverse solution, some additional constraint or assumption of the model parameters should be imposed during the inversion.

In geophysical applications, the physical properties usually can be described by a finite number of approximate values. If the finite values of the physical property can be acquired and be used as prior information, the model parameter could be reparameterization. And then the original inversion problem is transformed into a two-stage inversion method: firstly, the discrete values of the physical property are acquired form geological investigation or estimated by some fast inversion method or migration method; secondly, model structure can be recovered by a kind of shape reconstruction inversion method. The main feature of this inversion method is that the physical property values and model geometry structure are determined separately, not simultaneously.

The level set method is a powerful tool for extracting structural information, which is based on modeling propagating front and interfaces between the regions with different model parameters. This method is firstly introduced by Osher and Sethian (1988) and then has already be widely applied in many fields, such as image segmentation, inverse obstacle problems, inverse scattering problem and even geophysical inverse problem. Piecewise level set (PCSL) method is another kind of method for model parametric representation, which was proposed by Tai et al. (2006). PCSL method share the area division idea of level set method, which also use finite values of model parameter and a new level set function to rebuild the model function. This method has been demonstrated that it could recover model parameter distribution with rather complicated geometry of discontinuities under a moderate amount of noise in the observation data. There are some main difference between the traditional level set method and PCLS method. For multiple subdomains, traditional level set method generally use n level set functions to represent 2^n disjunct (non-overlapping) regions; the PCLS method need only one level set function to identify all the phases of the unknown parameter and form a portion of target area. From this point of parametric representation, PCLS method will make the algorithm to be simpler and more flexible, and also keep memory costs low. Consequently, PCLS method has already been applied to image segmentation, shape-optimization problems, and parameter identification successfully, but it has not yet been applied to potential inversion problems. However, according to the similar basic principle of parameterization as level set method, we believe that PCLS method can also be used to potential inversion problem.

Therefore, we introduce a new inversion algorithm for magnetic gradient tensor data, which is based on PCLS parameterization and MSTV regularization method. Combination of these two methods will fully utilize the advantage of magnetic gradient data and further improve the clarity and accuracy of reconstructed boundary of model parameter. We apply the new method to synthetic models and demonstrate its effectiveness.