

PAPER

3D CSEM data inversion using Newton and Halley class methods

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Abstract

For the first time in 3D controlled source electromagnetic data inversion, we explore the use of the Newton and the Halley optimization methods, which may show their potential when the cost function has a complex topology. The inversion is formulated as a constrained nonlinear least-squares problem which is solved by iterative optimization. These methods require the derivatives up to second order of the residuals with respect to model parameters. We show how Green's functions determine the high-order derivatives, and develop a diagrammatical representation of the residual derivatives. The Green's functions are efficiently calculated on-the-fly, making

use of a finite-difference frequency-domain forward modelling code based on a multi-frontal sparse direct solver. This allow us to build the second-order derivatives of the residuals keeping the memory cost in the same order as in a Gauss–Newton (GN) scheme. Model updates are computed with a trust-region based conjugate-gradient solver which does not require the computation of a stabilizer. We present inversion results for a synthetic survey and compare the GN, Newton, and super-Halley optimization schemes, and consider two different approaches to set the initial trust-region radius. Our analysis shows that the Newton and super-Halley schemes, using the same regularization configuration, add significant information to the inversion so that the convergence is reached by different paths. In our simple resistivity model examples, the convergence speed of the Newton and the super-Halley schemes are either similar or slightly superior with respect to the convergence speed of the GN scheme, close to the minimum of the cost function. Due to the current noise levels and other measurement inaccuracies in geophysical investigations, this advantageous behavior is at present of low consequence, but may, with the further improvement of geophysical data acquisition, be an argument for more accurate higher-order methods like those applied in this paper.

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