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Application of truncated Newton method in multiparameter FWI imaging

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Introduction

Full Waveform Inversion (FWI) imaging is an inversion technique aimed at simultaneously estimating subsurface velocity and reflectivity. One of the main challenges faced in multiparameter inversion is the coupling effects between different physical properties, known as interparameter crosstalk, which can lead to biased and unreliable model updates. Second-order optimization methods are promising in addressing this problem due to the ability of the Hessian matrix to mitigate multiparameter interferences. In this work, we investigate the application of the truncated Newton algorithm in FWI imaging, aiming to use the action of the multiparameter Hessian matrix as an alternative to reduce crosstalk effects in the estimation of high-resolution images for subsurface structures.

Method

The methodology is based on the multiparameter formulation of the inversion, obtained from the reparameterization of the variable-density acoustic wave equation, expressed in terms of the velocity $c(\mathbf{x})$ and the vector reflectivity $\mathbf{R}(\mathbf{x})$. We use the adjoint-state method to derive the expressions for the gradient, $\nabla_m J$, and for the action of the Hessian of the objective function on a perturbation, $H(m)\Delta m$. The truncated Newton algorithm is then applied to calculate the update direction of the model Δm through the iterative solution of the system:

$$H(m)\Delta m = -\nabla_m J, \tag{1}$$

where $m = [\, c(\mathbf{x}), \mathbf{R}(\mathbf{x}) \,]$ is the vector of model parameters, composed of the spatial distribution of velocity and vector reflectivity.

The computational implementation was tested in 2D synthetic models using the multiscale approach in the time domain, progressing from lower to higher frequencies to avoid the numerous local minima in the objective function and gradually incorporate small-scale heterogeneities into the models.

Results and Conclusions

Preliminary results are being analyzed in experiments applied in the *Marmousi2* model, with the aim of evaluating the effectiveness of using the inverse Hessian diagonal as a preconditioner for the gradient in the Eq. 1, as well as the impact of the Hessian action in mitigating interparameter crosstalk during the simultaneous estimation of high-resolution velocity and reflectivity models. This application is expected to enhance the distinction between velocity and reflectivity parameters, resulting in more accurate updates and with less presence of coupling artifacts, compared to first-order methods. Final results will be presented during at the conference.