Submission code: WLAGW580LB

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Comparisons of FWIs with different objective functions

Pablo Machado Barros (Cenpes-Petrobras), André Bulcão (Petrobras), Bruno Pereira Dias (Petrobras), Claiton Pimentel de Oliveira (Petrobras), Djalma Manoel Soares Filho (Petrobras), Gustavo Catão Alves (Petrobras), Tiago Ilipronti Girardi (Cenpes-Petrobras), Ubiratan Jose Furtado (Petrobras), Luis Fernando Mendes Cury (Cenpes-Petrobras)

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Introduction

Full Waveform Inversion (FWI) has been widely applied in the oil and gas industry, mineral exploration, and geotechnical studies, offering superior spatial resolution for determining the properties that affect the propagation of seismic waves compared to other methods and a better representation of geological characteristics.

The essence of FWI lies in minimizing the difference between the seismic traces calculated from an underground model and the observed seismic waves (real seismic data). For this purpose, objective functions are used to quantify this discrepancy. This function can be minimized through different methods, such as the method of steepest descent, Newton's method and its variants and the conjugate-gradient method. The gradient of the objective function, which is necessary in the methods mentioned, is calculated using the adjoint state method. These methods iteratively adjust the subsurface property model to minimize the objective function.

Different objective functions can be employed, such as the L2 norm, which is the most common and allows for fine-tuning of the model. However, the L2 norm is subject to the cycle skipping problem, which can trap the objective function in a local minimum, thus preventing the progress to a global minimum. To mitigate this issue, the multi-scale approach, regularization techniques and other objective functions have been proposed in the literature. For instance, the multi-scale approach for the frequency starts the inversion with the low frequencies of the data and, step by step, includes the higher frequencies. The multi-scale approach can also be done using offset, layer striping, etc. Regularization uses prior knowledge to guide the inversion towards the desired model. Examples of other objective functions are the adaptive norm, functions that use the envelope or phase of seismic traces, time-lag norm, cross-correlation, etc.

That said, this work aims to compare the robustness of some functionals reported in the specialized literature, evaluating convergence, spatial resolution of the solution and other metrics, as well as the influence of the initial model, which also affects the efficiency of the inversion.

Method and/or Theory

Investigations for the Marmousi2D geological model are underway with different objective functions using the adjoint method for various initials models. Other synthetic geological models will be tested to determine which is the best objective function or which is the best according to the complexity of the geology faced.

Conclusions

In summary, Full Waveform Inversion (FWI) represents a significant advancement in seismic processing that could lead to better seismic interpretation, allowing for a more accurate understanding of subsurface characteristics. Objective functions play a central role in this process, guiding the optimization of the model and ensuring that the estimates are both accurate and relevant for practical applications in the exploration and production of natural resources. The continuous evolution of FWI techniques, coupled with increased computational capacity, promises further improvements in the quality and efficiency of seismic inversions.