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Estimation of elastic parameters using multichannel blind inversion of elastic impedance and comparison of it with Bayesian AVO inversion

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Extended Abstract

Summary

Elastic parameters can be retrieved from pre-stack seismic data using the concept of the elastic impedance (EI). As the first inversion method in this study, an inversion algorithm is used that recovers the elastic parameters from pre-stack seismic data in two sequential steps. In the first step, using the multichannel blind seismic inversion, blocky EI models are obtained from partial angle-stacks. Using total-variation (TV) regularization, each angle-stack is inverted in a multichannel form. The second step involves the inversion of the resulting EI models for elastic parameters. Mathematically, the EIs are linearly described by the elastic parameters in the logarithm domain. Thus, a linear least-square inversion is employed to perform this step. Furthermore, elastic parameters are inverted through linearized Bayesian AVO inversion as the second inversion method, and some posterior distribution for elastic parameters is proposed. Finally, the results of both inversion methods are compared and their advantages and shortages are discussed.

Introduction

EI provides a framework to obtain the elastic parameters by inverting seismic data. EI is a nonlinear function of P- and S-wave velocities (Vp and Vs) and density (ρ), therefore, elastic parameters can be extracted from a set of EI parameters corresponding to different angles via a least-square method.

In this study, we use a high-resolution algorithm, which determines elastic parameters from pre-stack seismic data in two steps of EI estimation followed by an inversion for the elastic parameters. Clearly, due to the effects like anisotropy, wavelet should be considered as a function of the incident angle. Here, we employ some multichannel blind seismic inversion to obtain both the EI model and the corresponding wavelet for each angle-stack. The EI and wavelet are automatically obtained via an iterative process. The EI is required to have a blocky structure, in the sense of the total-variation (TV) norm, while satisfying both the data and a priori low-frequency information.

The inversion of EIs for the elastic parameters is easily performed by a least-square fitting strategy. As the second method of estimating elastic parameters, a linearized Bayesian AVO inversion method has been used to estimate posterior distribution of elastic parameters directly from seismic data and the MAP (maximum a posterior) solution is calculated. In general, Bayesian inversion provides a relation between posterior distribution, prior information and the conditional distribution of observed data when the model is known. As the aim of this study, the results of both algorithms are compared and discussed.

Methodology and Approaches

For estimation of EI, we optimize a cost function, which is defined as a multichannel problem, where total variation norm of EI model is expected to be minimum, and also, the mode predicts the seismic data and satisfies some priori information about low frequency content of model.

Bringing EI equation in logarithm domain and using EIs for different angles, a linear inverse problem can be defined and a damped least-square solution can be obtained.

For Bayesian approach, assuming log-normal distribution as priori information about elastic parameters, in logarithm domain, it comes into normal and the posterior distribution will also be normal and model posterior mean and covariance can be expressed explicitly. We select the MAP solution and compare it with damped least-square solution.

For each approach, related software is developed in MATLAB.

Results and Conclusions

The results show that both inversion methods, presented in this paper, are successful in estimation of elastic parameters with a good degree of precision. The deterministic inversion method is multichannel and has a better resolution. Moreover, it is blind and wavelet is taken as an unknown. However, this approach fails in estimation of low-frequency part of parameters but the Bayesian inversion approach recovers the low frequency part very well.