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Constant Q estimation from a seismic trace and its removal by non-stationary deconvloution

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Extended Abstract

Summary

The visco-elasticity of the earth causes dissipation of the energy of seismic waves when traveling through a medium, a phenomenon referred to as seismic attenuation. The attenuation property of a medium is described by a quantity called quality factor, or Q, which describes the amount of energy loss. The quality factor is related to the frequency of the propagation wave. In seismic data processing, our knowledge about this quantity is used to enhance the quality of seismic data, as an increase in the temporal resolution of the data, via absorption compensation tools. An exact formulation of seismic attenuation and its effect on the recorded data are unknown but there are simple models for describing the attenuation behavior approximately. The constant Q model relates a single value for Q to all frequencies in a trace. An important step in dealing with absorption compensation is the estimation of Q value. There are some methods for estimation of Q. In this paper we formulate Q estimation as a non-linear inverse problem. The value of Q is found by the optimization over the sparsity of the reflectivity describing the trace with a given wavelet. Numerical tests using simulated and field data are presented showing high performance of the proposed method for Q estimation and high-resolution non-stationary deconvolution.

Introduction

Conventionally, in seismic exploration, the earth is modeled as an ideal elastic medium, and seismic wave propagation is explained by means of the elastic wave equation. In practice, however, the propagation of seismic waves in the earth is in many respects different from seismic wave propagation in an ideal solid. For example, the earth material is anisotropic, heterogeneous, porous, etc. The traditional elastic wave equation is not accurate enough to describe the wave behavior for this complicated medium. Generally, the visco-elasticity of the earth materials causes seismic energy dissipation, and thus, decreases the amplitude of propagating waves. By elimination of the effects of this phenomenon from the observed seismic data, we may be able to construct images with better resolution through seismic data processing and extract more detailed information about the rock materials through seismic data inversion. There are some simple models to describe the behavior of seismic energy loss. In this paper, we assume the constant Q model for earth and we compensate the effects of wavelet and seismic attenuation simultaneously from a trace. In the case of layered earth models, non-stationary deconvolution using true value of Q, can lead to a sparse reflectivity series. This point is the key assumption in this paper.

Methodology and Approaches

According to the convolutional model of the earth, a seismic signal can be modeled as convolution of the source generated wavelet with the earth impulse response including the effects of attenuation. Thus, we can formulate a noise free trace as y=WAr, where y is the seismic trace, W is a Toeplitz matrix of initial wavelet and A is the attenuation operator as a function of Q, and r is the earth impulse response.
For layered earth models, the seismic earth impulse response is a sparse time series. Therefore, if we solve the following non-linear optimization problem

$$\underset{Q}{\arg\min} \|r\|_0 \qquad s.t. \qquad \|y - WAr\|_2^2 \le \delta \qquad (1),$$

we can find a Q that gives the sparsest reflectivity. However, solving this non-linear optimization is very hard, and instead of solving the above optimization problem, we solve

$$\underset{r}{\arg\min} \|r\|_1 \quad s.t. \quad \|y - WAr\|_2^2 \le \delta \qquad (2)$$

for different Q values and select those values leading to the sparsest reflectivity.

Results and Conclusions

We have proposed a method, based on non-stationary sparse deconvolution, for estimation of constant Q factor for a seismic trace. Numerical examples from simulated and field data indicated that the new method, in comparison with some conventional methods, provides better results. It was observed from numerical examples that the new method works well for low Q values and low signal to noise ratios.