A hybrid method for AVO inversion

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ABSTRACT

Global optimization algorithms are generally computationally intensive processes, where a significant amount of time is required to generate a solution. Therefore, methods to improve the efficiency are desired for problems that require their use. In this study we present a hybrid method to improve the convergence rate of an AVO inversion through implementation of a trace integration method followed by a simulated annealing optimization. The method eliminates the need for an additional model parameter to represent the layering solution and reduces the compute time of the global optimization by generation of an initial model that is close to the final solution.

INTRODUCTION

- Inverse problems that contain local minima in their objective function require the use of global optimization algorithms
  - Large computational costs
- Conditioning of initial model to a state that is close to the final solution can greatly reduce the compute time
- In this study, we attempt to minimize the compute time associated with an AVO inversion
  - Implementation of a trace integration method followed by a simulated annealing optimization
- We first present the problem formulation and subsequently demonstrate the methodology to obtain the inverse solution

PROBLEM FORMULATION

- In an AVO inversion, the objective is to estimate the P- and S-wave velocities and density from the angle-dependent reflectivity
  - Typically achieved through iteratively updating an initial model until the data residuals are minimized
- Low frequencies (subscript 0) from well logs and high frequencies (prefix Δ) from seismic

$$\alpha = \alpha_0 + \Delta\alpha \qquad \beta = \beta_0 + \Delta\beta \qquad \rho = \rho_0 + \Delta\rho$$

- Impedance estimate can be obtained through (e.g. Oldenburg et al., 1983)

$$I_{j+1} = I_1 \exp\left(2\sum_{k=1}^{j} r_k\right)$$

- Subsequently, the low frequency models α_0, β_0 and ρ_0 can be used to obtain an initial model

$$\alpha^{(initial)} = \frac{I}{\rho_0} = \alpha\left(1+\frac{\Delta\rho}{\rho_0}\right)$$

$$\beta^{(initial)} = \alpha^{(initial)}\left(\frac{\beta_0}{\alpha_0}\right)$$

$$\rho^{(initial)} = \frac{I}{\alpha_0} = \rho\left(1+\frac{\Delta\alpha}{\alpha_0}\right)$$

  - Errors on the order of property reflectivities (small quantities)
  - Layering solution given by zero crossings upon subtraction of low frequency trend

INITIAL MODEL GENERATION

- Synthetic data generated from measured well logs (P, S and density)
  - Angle reflectivity from Aki and Richards equation (1980)
  - Convolve with [0 10 50 60] Ormsby wavelet
- Initial model generated by trace integration of near angle seismic and the addition of the low frequency model through a series of filtering operations

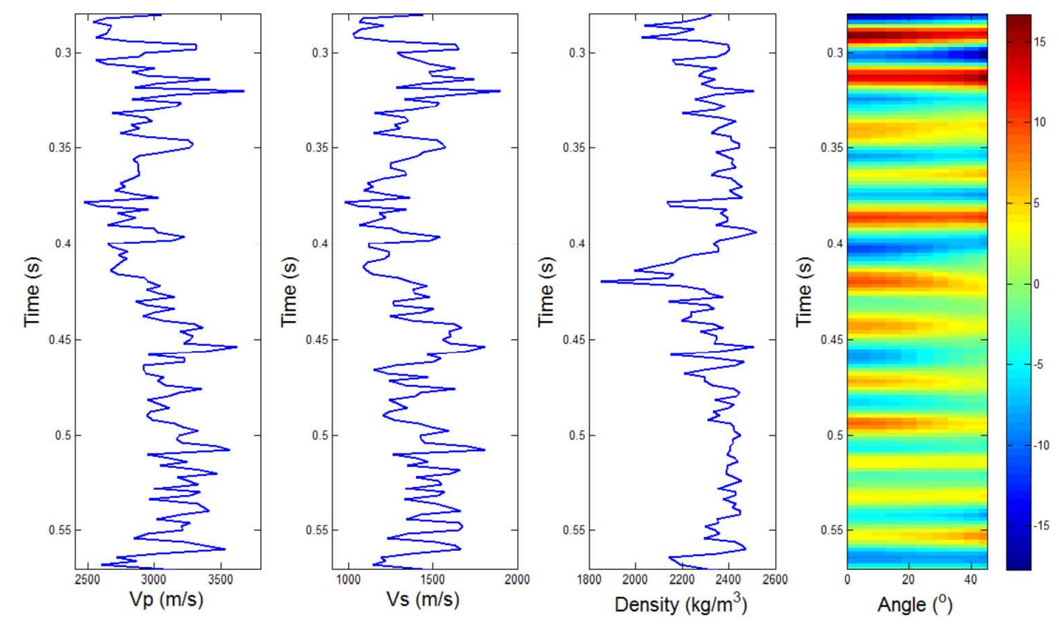

FIG. 1. P- and S-wave velocity and density well logs and the associated angle gather.

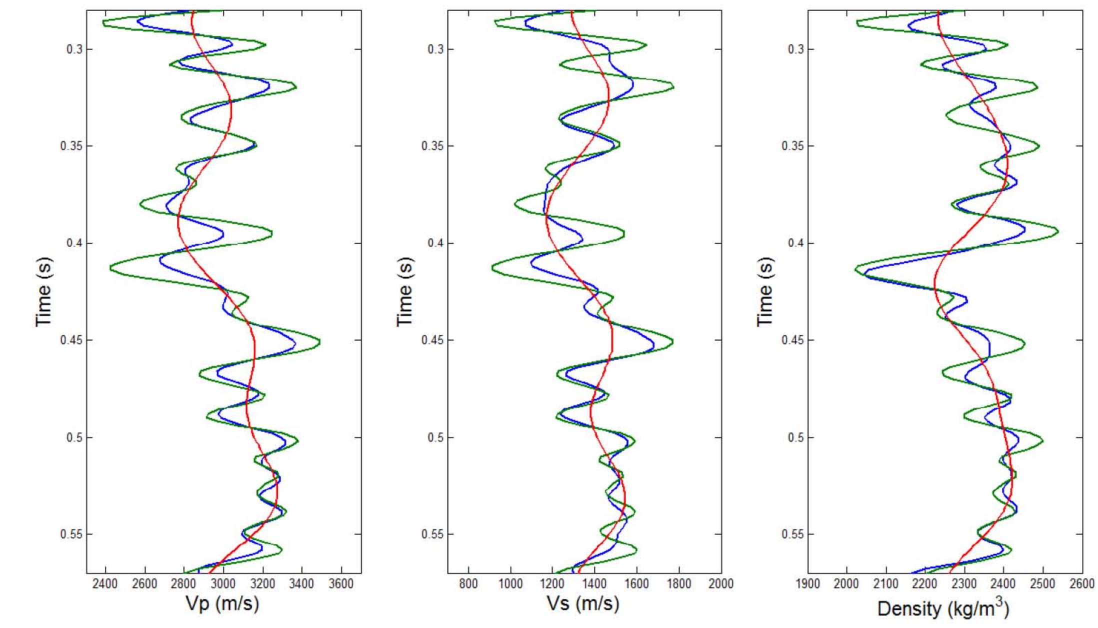

FIG. 2. Low frequency (red), true (blue) and initial (green) model for the P- and S-wave velocity and density.

INVERSION

- Implement a simulated annealing approach as in Cho and Margrave (2012)
  - Iteratively perturb model layer by layer to minimize objective function

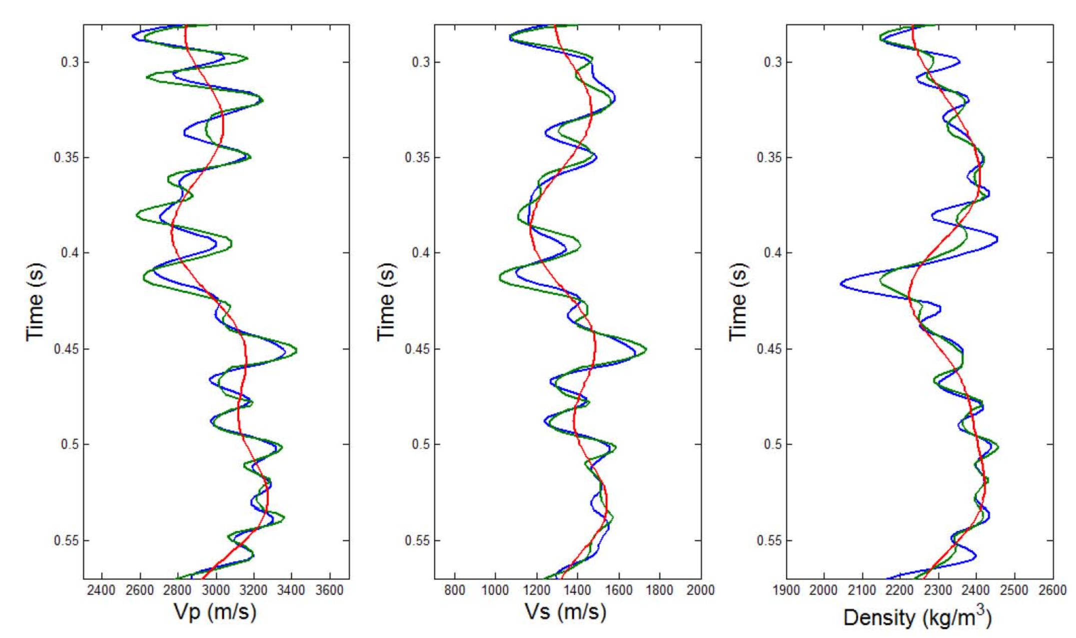

FIG. 3. Low frequency (red), true (blue) and estimated (green) model for the P- and S-wave velocities and density.

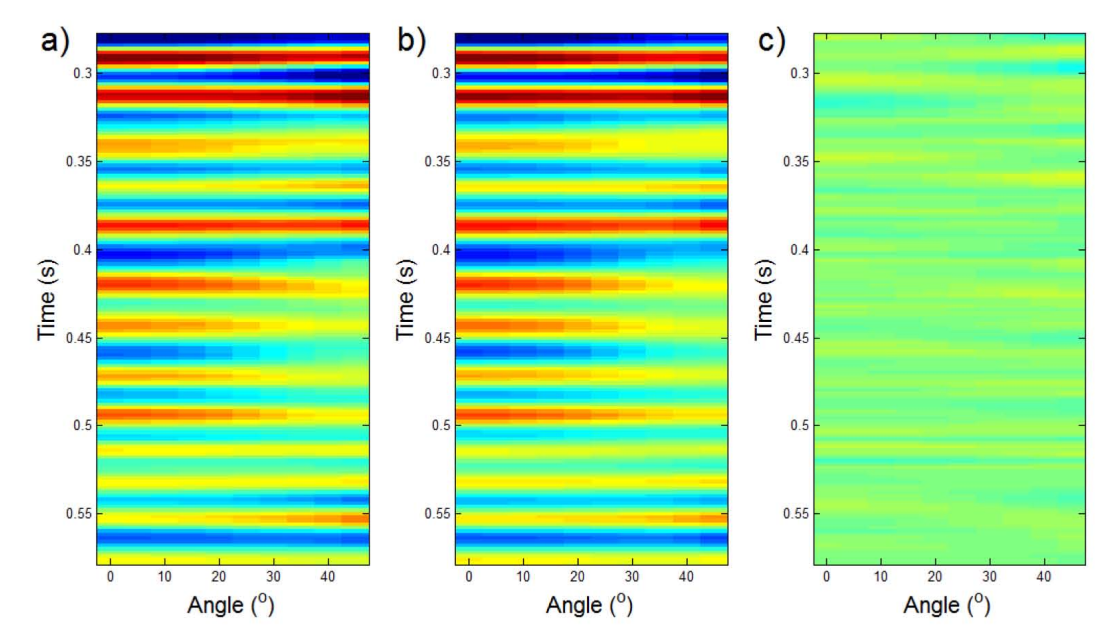

FIG. 4. Seismic angle gathers for the a) input data, b) synthetic data and c) residuals (color scale is the same for all panels).

CONCLUSIONS

A hybrid method to improve the convergence rate of an AVO inversion was presented. A trace integration method was performed to obtain a layering solution and an initial model that consist of small errors on the order of the property reflectivities. Subsequently, a global optimization algorithm was applied to refine the solution to achieve the final result. Using this approach, a separate model parameter representing the layering solution is not required. In addition, the time devoted to the computationally intensive global optimization is reduced due to a pre-defined layering solution and an initial model that is close to the final solution.