Inclusion of spatial sampling and migration artefacts in AVO/Az analysis using Kirchhoff approximation

Hassan Khaniani* and Daniel Trad
khaniani@ucalgary.ca

Introduction

- We quantify the uncertainty of linearized Amplitude Variation with Offset/Azimuth (AVO/Az) analysis of seismic P-P wave in a Horizontal Transverse Isotropic (HTI) model.
- We use Kirchhoff scattering and imaging operators to modify analytical values of AVO/Az based on the numerical artefacts produced by poor sampling and deficiencies of the operators to reproduce true amplitude migration.
- We present a multiparameter inversion for azimuthal parameters based on the reconstruction of total waveforms by representation on numerical dictionaries obtained by optimization.
- The method is applicable to precritical reflection data acquired from 3D anisotropic media.
- We show that the inclusion of the artifacts of acquisition and processing in the numerical estimation of AVO/Az values improves the accuracy of conventional analytical curve fitting.

Objective of this study

- A pattern search algorithm is developed to construct the total waveform of modeled AVO/Az properties using several waveforms resulted from reflectivity function parameters.
- This algorithm forms a dictionary of basis functions for the target, then performs constrained least squares fitting search by combination of weight multiplier and the basis dictionary.
- We show that the solution of this approach is more stable compared to analytical curve fitting due to inclusion of numerical artifacts and the constraint of the solution by flexibility in the range of the multiplier.

HTI reflectivity function (Rüger, 1997)

$$R_P^{HTI}(\theta,\varphi)=\sum_{k=1}^{6}\alpha_k\psi_k,$$

where, ψ_k are defined as

$$\psi_1=\frac{\Delta v_P}{\bar{v}_p},\psi_2=\frac{\Delta Z}{\bar{Z}},\psi_3=\frac{\Delta G}{\bar{G}},\psi_4=\Delta\delta,\psi_5=\Delta\varepsilon,\ \text{and}\ \ \psi_6=\Delta\gamma.$$

The coefficients are defined by,

$$\alpha_1=\frac{1}{2}tan^2\theta,\alpha_2=\frac{1}{2},\alpha_3=-\frac{1}{2}\left(2\frac{\bar{v}_S}{\bar{v}_P}\right)^2 sin^2\theta,$$

$$\alpha_4=\frac{1}{2}\left(1+sin^2\varphi tan^2\theta\right)cos^2\varphi sin^2\theta,$$

$$\alpha_5=\frac{1}{2}cos^4\varphi sin^2\theta tan^2\theta,\alpha_6=\left(2\frac{\bar{v}_S}{\bar{v}_P}\right)^2 cos^2\varphi sin^2\theta,$$

Why we use AVO/Az analysis for inversion?

- AVO/AZ is a standard workflow in seismic attribute analysis and hydrocarbon detection.
- The radiation pattern in seismic data is sensitive to subsurface multi-parameters.

Artefacts of acquisition and migration on AVO/Az analysis

- We need to constrain the effect of acquisition and migration on AVO/Az

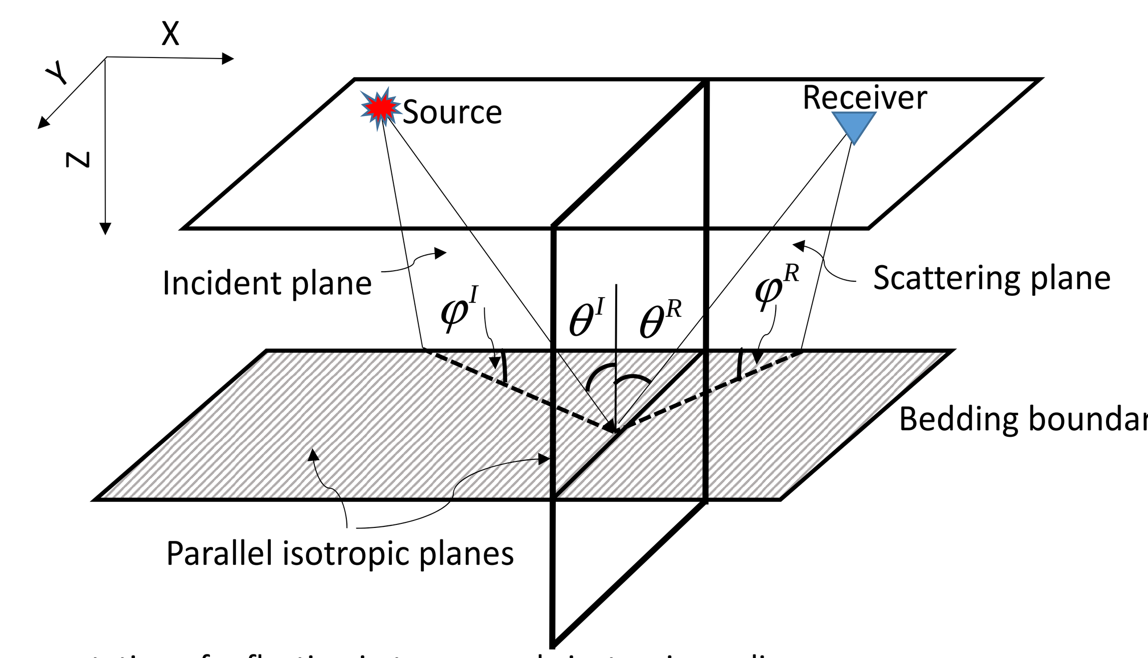

Fig.1. Schematic representation of reflection in transversely isotropic medium.

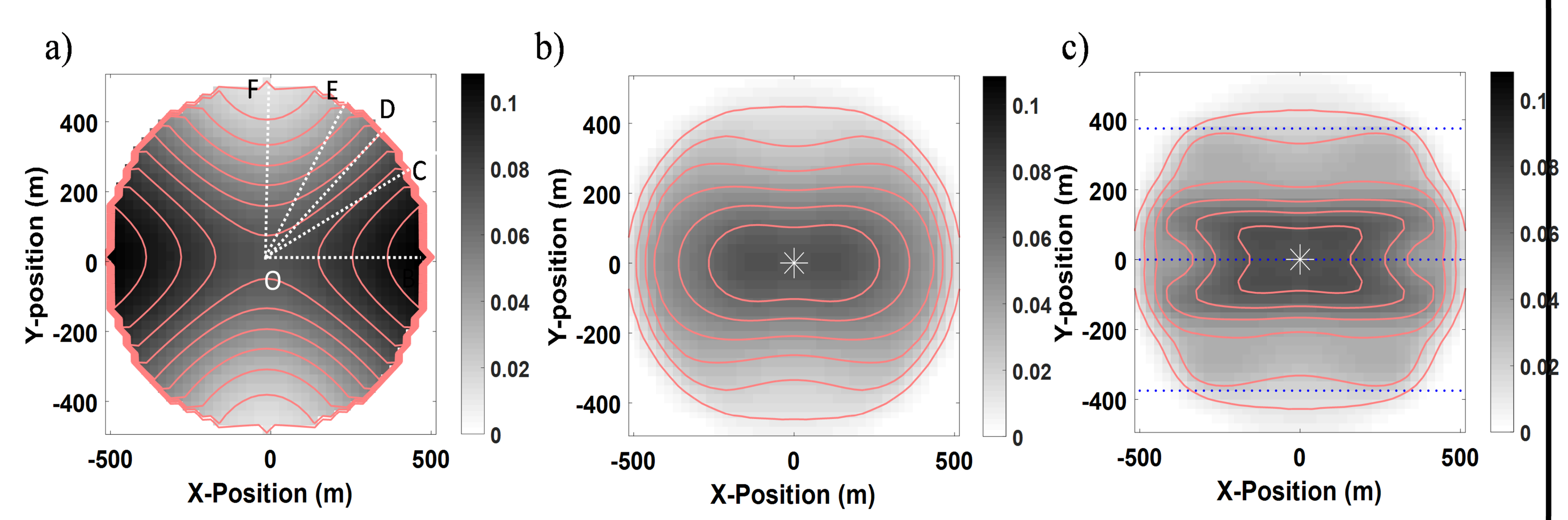

Fig.2. Evaluation of radiation patterns for an anisotropic HTI model. a) Analytical evaluation . b) Well-sampled Kirchhoff modeled data and c) the poorly-sampled modeled data.

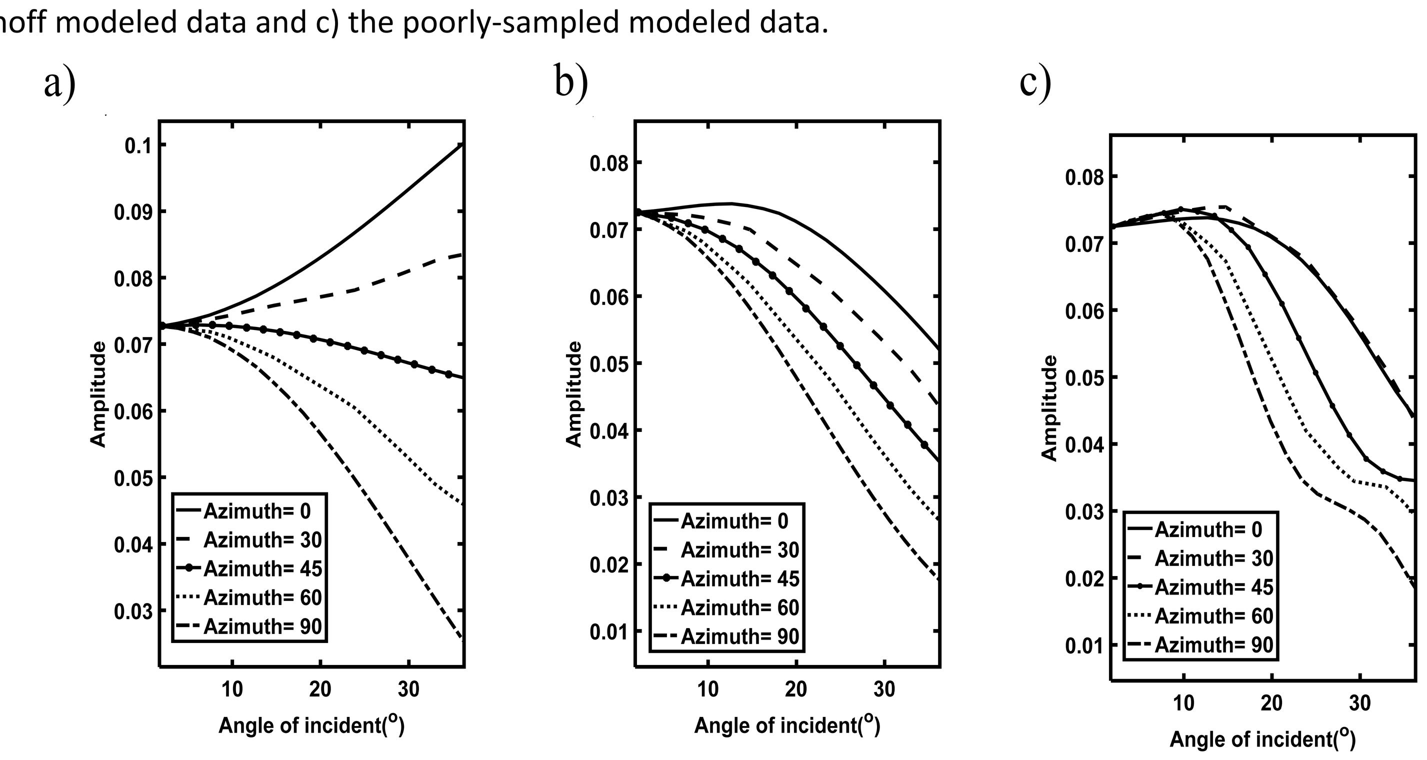

Fig.3. The values along OB, OC, OD, OE and OF directions in Figure 2

BASIS DICTIONARY FITTING (BDF) algorithm

In this study, as shown in Figure 8, we implement a direct pattern search algorithm that is based on a constrained bounded least-squares problem. For each perturbed model a linear fitting objective function is minimized according to,

$$S=\left\|G^T d-F\right\|_2+\eta\left\|1-ncorr\left(G^T d,F\right)\right\|_1,$$

where, F is define as

$$F=\left(\sum_{\lambda=1}^{N_k}\sum_{k=1}^{6}w_{\lambda k}G^T G\left(\psi_k\right)\right).$$

The weights multiplier $w_{\lambda k}$ with the subscripts λ varies from 1 to the number of weight coefficients for fitting N_k. The regularization term η and normalized cross correlation operator $ncorr$ ensures that the radiation pattern of the constructed waveform has a shape similar to the pattern of the field data. This algorithm constructs the migration result by a combination of basis dictionary functions and multipliers.

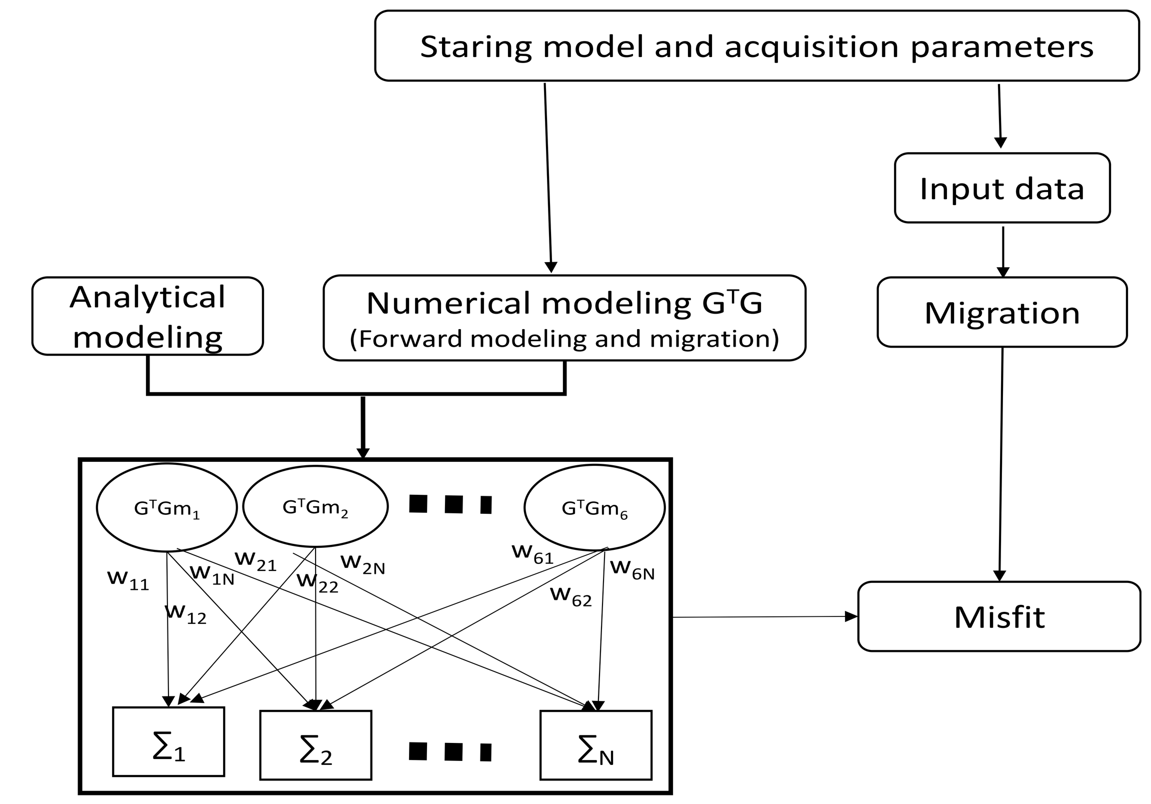

Fig.4. Flow work for AVO/Az analysis using basis dictionaries and constrained solution.

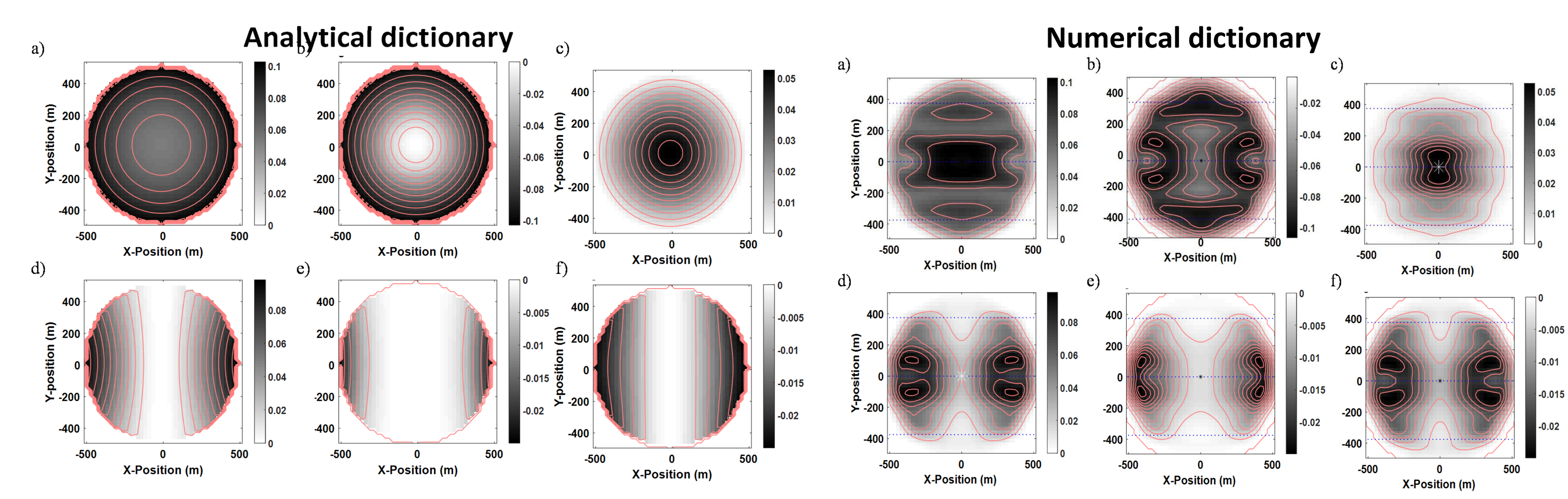

Fig.5. Basis function for the analytical and numerical dictionary. The panel in a), b) and c) are the evaluation of isotropic parameters, $\alpha_1=\alpha_2=\alpha_3=0.1$ respectively. The panel in d), e) and f) are the evaluation of anisotropic parameters, , $\alpha_5=0.1$, and $\alpha_4=\alpha_6=-0.1$ respectively.

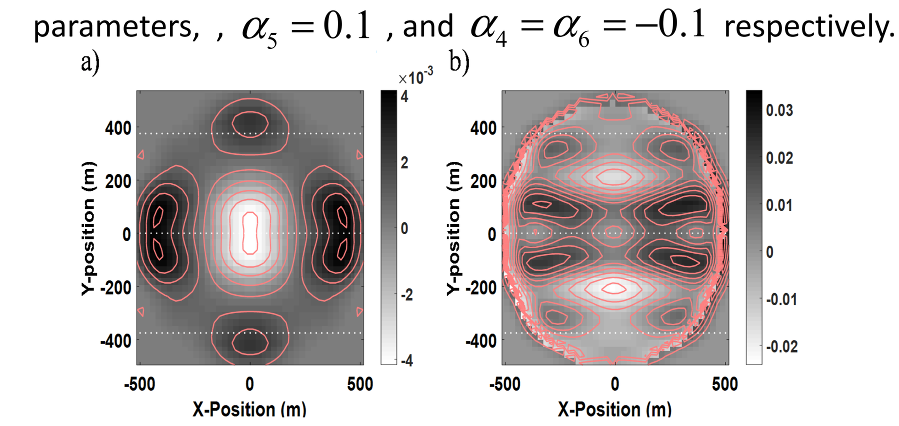

Fig.6. The residual norm of migration of true and modeled data from a) numerical evaluation and b) analytical evaluations.

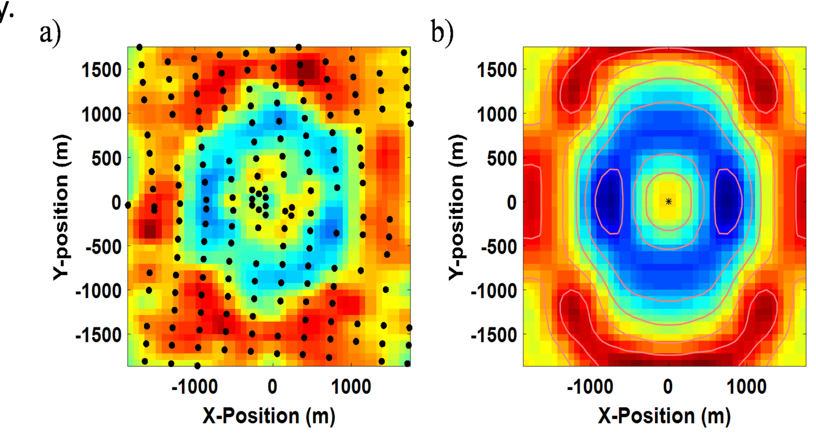

Fig.7. A field data in (a) is reconstructed using BDF waveform in (b)

Acknowledgments

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