Full Waveform Tomography

Problem Statement
Full Waveform Tomography (FWT) based on the Adjoint-Wavefield (AW) and Scattering Integral (SI) methods can be used to iteratively improve crustal velocity models through a process called inversion. In FWT, the wavefields are generated by numerical solutions of the 3-D elastodynamic/ visco-elastodynamic equations according to a specific velocity model and then compared with the observed data to extract the misfit between the current model and true model. This project comprises several objectives where FWT is applied in increasingly complex applications, starting with a synthetic test for verification purposes, next moving to a regional application for the Canterbury region, and finally for a New Zealand-wide application. Current intentions are to use the Adjoint-Wavefield method. (For inversion, a number of misfit measurements based on 146 earthquake seismograms for 43 seismic stations in the Canterbury region are used as the observed data. After a number of inversion iterations, the final inverted model using FWT has good potential for more accurate simulation of ground motion for the Canterbury region, and provides a platform for extension of this method to the wider New Zealand region.) - Move this to the inversion of the crustal velocity model for Canterbury region page
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Description (Objectives / Outcomes)
1. Synthetic study of FWT for a 1-D velocity model. 2. Inversion of the crustal velocity model for Canterbury region. 3. Verification of FWT

Comparison of existing FWT methods*

Existing FWT methods	Adjoint Wavefield Method (Adjoint-Gradient Method)	Scattering Integrals Method (Gauss-Newton Method)
Forward modelling	Generate the forward wavefields as time series at every cell in the spatial domail (3 ground velocity componets or 6 stress components) for every source as well as the synthetic data according to the station locations	• Calculate the equivalent body forces (13 components) for every source and the synthetic data according to the station locations • Generate the forward wavefields as in AW method
Storage of the wavefield	• Store the forward and backward wavefields seperately and canculate the kernels after that. The displacement residual are calculated from syhtnetic and observed data. • Store the forward wavefield and do kernel calculation on the fly together with backward simulations. • Store the last state of the forward wavefield and do kernel calculation on the fly together with backward simulations and reconstruction of the forward wavefield.	• Store the equivalent body forces for every source and calculate/ store the Jacobian matrix according to each receiver. The velocity residual are calculated from synthetic and observed data for convolving with the source to remove the influence of the source signature. • Store the backward wavefield according to each receiver as an adjoint source for one specific source. Using Green's tensor estimation to generate the backward wavefield according to the remaining sources.
Kernel calculation	• Calculate the sensitive kernels from the velocity wavefields • Calculate the sensitive kernels from the stress wavefields	• Calculate the gradient matrix on the fly by summing up the product of Jacobian matrix and the convolved residual. Estimate the Hessian matrix from the stored Jacobian matrice. Get the search direction by multiply the inverted Hessian matrix to the gradient. • Calculate the sensitive kernels from the wavefields like in AW method
Adjoint source	Displacement residual, multi-channel source (applied at all receiver locations)	• Use a reference source (true source, Ricker wavelet, etc..) • Use a velocity time serie from one channel of the observed data picked-up by GSDF method.
Number of simulations (as minimum required)	2 X Ns	Ns+3 X Nr
Number of time integrations		
Optimization algorithm	Conjugate - Gradient, BFGS	Gauss-Newton
Optimal step length (Number of iterations needed to match one Gauss–Newton step)	Yes	No

Schedule

Current Questions

1. What adjoint source is being used? (The sumation of Gaussian wavelets using GSDF method?)
2. Is subsampling currently implemented for saving wavefields?
3. What method of adjoint wavefield storage is used?
4. What is the work flow for one iteration of FWT applied in the Southern Mexico?

*** References**

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3. Tromp, J., Tape, C. & Liu, Q., 2005. Seismic tomography, adjoint methods, time reversal and banana-doughnut kernels. Geophysical Journal International, 160, pp.195-216.
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