

Results: Numerical Examples

We show the implementation of equations 1, where S is a transparent boundary. For this elastic scenario, we save five different wavefields $v_x(\mathbf{x}_S, t)$, $v_z(\mathbf{x}_S, t)$, $\tau_{xx}(\mathbf{x}_S, t)$, $\tau_{zz}(\mathbf{x}_S, t)$, and $\tau_{xz}(\mathbf{x}_S, t)$.

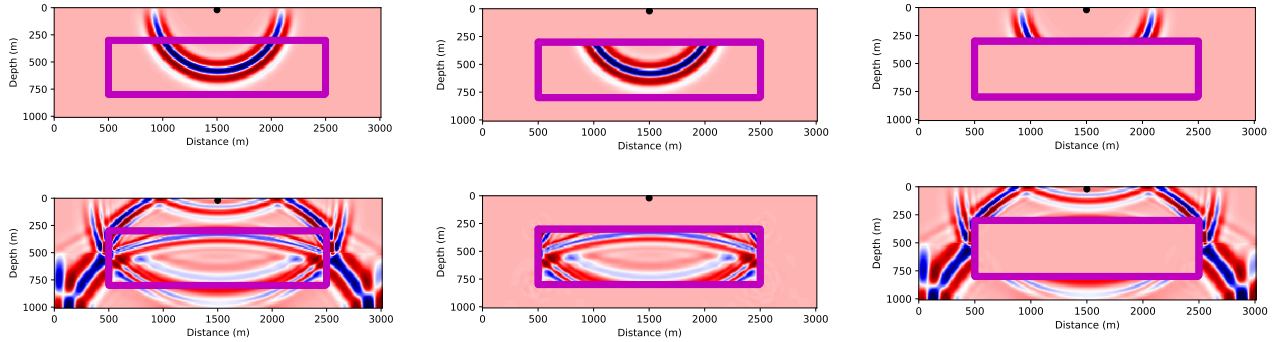


Figure 1: Stress τ_{xx} snapshots of left column: the original wavefield, middle column: injection of the wavefield and right column: difference between left and middle snapshots. Top row: constant velocity model, bottom row: two layer velocity model.

For demonstration purposes, we use a second-order FD scheme to model the response for a source located at $x = 1.5$ km and $z = 0.2$ km in an elastic constant velocity model with $V_p = 2.0$ (m/s), $\rho = 2.0$ (kg/m³) and $V_s = 0.88$ (m/s) and a two layer velocity model with $V_{p1} = 2.0$ (m/s), $V_{p2} = 4.0$ (m/s), $\rho_1 = 2.0$ (kg/m³), $\rho_2 = 2.3$ (kg/m³) and $V_{s1} = 0.88$ (m/s), $V_{s2} = 1.54$ (m/s). We use indices 1 and 2 in the top and bottom layer respectively. The five wavefields for the injection are recovered at the magenta points shown in figure (1), then the recorded data are injected using equation (1). Figure (1) illustrates the results of modeling with the local solver. After doing the difference between the original wavefield and the reconstructed wavefield (Figure 1, right column), we calculate an average error, which is $E_c = 5.6 \times 10^{-5} \%$ for the constant model and $E_T = 4.3 \times 10^{-4} \%$ for the two layer model. The implementation in any seismic modeling tool is easy. We use Devito to implement the method (Louboutin et al. 2017).

Conclusions

We have described the implementation of the MPS method in a centred staggered FD scheme for the elastic isotropic wave equation in the velocity-stress formulation, and its applicability in an elastic to elastic local solver. We show that using only one surface and five wavefields we are able to accurately retrieve the wavefield within a subdomain. The MPS method thus requires significantly less storage than alternative reconstruction methods such as the method of

Robertsson and Chapman (2000). Because the injection of the wavefield takes place by specifying point sources rather than by changing the parameters of the finite difference stencil, the implementation with any existing seismic modeling tool is straightforward.

Acknowledgment

This work is supported by Chevron and with grants from the Natural Sciences and Engineering Research Council of Canada Industrial Research Chair Program (IRCPJ 491051-14) and InnovateNL and by the Hibernia Management and Development Corporation. We gratefully acknowledge the assistance of the resources and staff of Compute Canada in the computations shown here.

References

Louboutin, M., Witte P., Lange, M., Kukreja N., Luporini, F., Gorman, G. and Herrmann, F. J. [2017] Full-waveform inversion, Part 1: Forward modeling. *The Leading Edge* **36**(12), 1033-1036, doi=10.1190/tle36121033.1.

Robertsson, J.O.A. and Chapman, C.H. [2000] An efficient method for calculating finite-difference seismograms after model alterations. *Geophysics*, **65**(3), 907-918, doi=10.1190/1.1444787.

Virieux, J. [1986] P-SV wave propagation in heterogeneous media: Velocity-stress finite-difference method. *Geophysics*, 51(4), 889-901, <https://doi.org/10.1190/1.1442147>.

Wapenaar, K. [2007]. General representations for wavefield modeling and inversion in geophysics. *Geophysics* **72**(5), SM5–SM17, doi: 10.1190/1.2750646.