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Designing a robust seismic full waveform inversion scheme: an extension approach

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Full waveform inversion (FWI) has become the standard for high resolution subsurface imaging, in both academia and the industry. FWI is formulated as a data fitting procedure, where the fit between the observed and the synthetic seismograms is improved iteratively. The synthetic seismograms are computed through the numerical solution of a wave equation, they are compared to the observed ones, and the subsurface parameters are updated to improve this fit. This optimization problem is conventionally solved using gradient based optimization strategies, which update a given initial subsurface model iteratively. These optimization approaches often fail to converge to a meaningful solution, when the initial model does not explain the kinematics of the seismic data. That is, the time shift between the observed and synthetic seismograms in the initial model is too large. This is particularly true in active seismic experiments at the crustal scale, where the data lack low frequency content.

Our strategy relies on modifying the FWI algorithm, in order to help mitigate the ill-posedness of the problem. To do so, we introduce additional parameters to the problem, which help make FWI well behaved. Our strategy makes the receiver position a free parameter, which is included in the optimization. This allows our algorithm to better explain the data kinematically, when the model estimate is poor. Our approach gives rise to a challenging optimization sub-problem, which we solve using stochastic optimization strategies: namely, Markov-Chain Monte Carlo (MCMC), Simulated annealing methods, and Particle Swarm Optimization (PSO). The latter proved to be a good candidate for our problem. We have also investigated a deterministic optimization strategy, using a dynamic programming approach. This deterministic method is less expensive than the stochastic alternatives. We test our methods using various realistic synthetic cases, obtaining promising results. This has prompted us to extend the method to 3D FWI, and perform synthetic tests, in preparation for a real 3D data application. The preliminary 3D results in synthetic settings are promising.