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FULL WAVEFORM INVERSION IN MIGRATION BASED TRAVEL TIME FORMULATION

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Constructing a smooth velocity model (propagator, macro velocity constituent) in the depth domain, which is responsible for correct travel-times of wave propagation is a key element of the up-to-date seismic data processing in areas with complex local geology. Theoretically it could be obtained, along with the subsurface structure, by the Full Waveform Inversion (FWI) technique matching the observed and the synthetic seismograms (Tarantola, 1984). The L_2 norm is usually used for this matching, though other criteria are also considered. To minimize the misfit function and to find the elastic parameters of the subsurface, iterative gradient-based algorithms are usually applied. Such approach to solving seismic inverse problem proposed originally by Tarantola (1984) has been developed and studied in a great number of publications (see Virieux and Operto, 2009, and the references therein).

However, the straightforward application of FWI reconstructs reliably only the reflectivity component of the subsurface but fails to provide a smooth velocity (propagator) component of a model. In order to overcome this trouble G.Chavent with colleagues introduced Full Waveform Inversion in Migration Based Travel-Time formulation (2001). The main idea of this approach is to decompose model space into two orthogonal subspaces - smooth propagator and rough reflector with subsequent reformulation of the cost function.

Full Waveform Inversion formally is application of non-linear least squares for seismic inverse problem treated as a nonlinear operator equation

$$\mathcal{F}[m] = d.$$

Here the known right-hand side d is multi-source multi-receivers seismic data, $\mathcal{F}$ is a non-linear operator (forward map) which transforms the current model m to synthetic data.

Instead of regular non-linear least squares formulation of Full Waveform Inversion, when unknown function $c(x)$ is searched as

$$c_* = \underset{c}{argmin} \, \|\mathcal{F}(c) - d\|^2, \tag{1}$$

MBTT introduces the following decomposition of the model space:

$$m = p + r = p + \Pi_r \mathcal{M}(p) < s > .$$

Here $p \in P$ describes smooth macrovelocity, which does not perturb significantly direction of waves propagation, but governs their travel times. In contrast the **depth reflector** r describes rough perturbations of the model, which send seismic energy back to the surface, but do not change travel-times. The key moment here is interrelation $r = \Pi_r \mathcal{M}(p) < s >$ where s is unknown **time reflectivity**, $\mathcal{M}(p)$ - a true amplitude prestack migration operator with linear reweighing W and Π_r is the orthogonal projector onto the space of reflectors (orthogonal to the space of propagators).

In this notations MBTT formulation of FWI with respect to propagator p and time reflectivity s is as follows:

$$(p^*, s^*) = \underset{p,s}{argmin} \, \|\mathcal{F}(p + \Pi_r \mathcal{M}(p) < s >) - d\| \tag{2}$$

The numerical examples show that non-linear FWI in MBTT formulation is able to reconstruct the true macrovelocity models, as opposed to the standard L_2 FWI.

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