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FULL WAVEFORM INVERSION IN TIME-DOMAIN FOR GEOPHYSICAL APPLICATIONS

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To obtain information about the earth's interior, oil and gas companies perform thousands of acoustic experiments by setting off "shots" and recording on the surface the waves reflected off internal heterogeneities. This is an example of one of the main tasks in data processing, i.e., identifying model parameters from observed data.

Most common seismic processing techniques require a velocity model to image the subsurface based on the recorded wave data. An approach that allows one to recover the velocity field is to cast the parameter recovery as a suitable inverse problem. This involves minimizing a least-squares misfit between synthetic and observed data. To solve the inverse problem, the adjoint-state method, first developed in [2], is employed. This approach originated from control theory [4]. Then A. Tarantola popularized it for seismic inversion in [6]. The resulting method is based on an augmented (associated) Lagrangian, which is obtained by adjoining the forward problem (the constraint) to the misfit functional, and by adding a possible regularization (Tikhonov-like) term. Then the first-order optimality conditions are obtained by enforcing the stationarity of the Lagrangian, yielding the so-called Karush-Kuhn-Tucker (KKT) system. The adjoint-state variables evolve backwards in time, and provide a natural measure of the sensitivity of the functional to changes in the model. This approach is attractive from the numerical viewpoint because the computation of the gradient of the misfit functional with respect to the model parameters amounts to performing an evaluation of the forward and of the backward modeling. The associated cost is often almost independent of the number of model parameters, which is not always the case when the Fréchet derivatives of the state variables with respect to the model parameters are directly computed.

In this communication we show some results concerning the recovery of model parameters for acoustic approximations of the elasticity equations, for material with Transverse

Isotropy (TI), in the framework of Full Waveform Inversion (FWI) in time-domain. Transverse isotropy is observed in sedimentary rocks at long wavelengths. Each layer has approximately the same properties in-plane but different properties through-the-thickness. The plane of each layer is the plane of isotropy and the vertical axis is the axis of symmetry. From the mathematical side, we deal with linear hyperbolic-type (systems of) equations, where the models are represented by the wave speed and the Thomsen parameters. Numerically, an explicit time-marching scheme based on finite differences is employed to discretize the resulting system.

Finally, we address recent developments about the so-called Tomographic Full Waveform Inversion [1, 5]. This consists of extending the velocity model through additional degrees of freedom, e.g., a time-lag or a space-lag, in order to overcome the major limitation of FWI, i.e., its sensitivity to the initial velocity model. In fact, if the initial velocity is not appropriately chosen, the iteration process may get stuck in one of the many local minima of the objective functional, instead of converging to the global minimum.

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