Non-regression pre-stack AI-based seismic inversion algorithm

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Rock properties can be estimated by performing a seismic inversion. Seismic pre-stack inversion approaches are based on the fundamental assumptions: linearisation of the Zoeppritz equation, estimation of impedances or elastic parameters and extraction of the linked velocity and density through regressions. The regression limitations come from an ill-posed problem that gives equivalent solutions for a large ensemble of rock properties. To reduce uncertainties in the regression approaches, statistical and advanced clustering techniques are commonly used. However, the environment does not obey regression laws everywhere.

We propose to overcome the regression limitations by solving the problem radically differently. Here we demonstrate that combining metaheuristic procedures, designed artificial constraints, and computation-efficient schemes reveals the unexampled possibility of estimating non-linked rock properties from the seismic data.

For each inversion iteration, we individually update the model parameters of Vp, Vs and Dn in a random scheme. Synthetic traces are calculated for each iteration, and we compute a global misfit between the synthetic and real data. In our approach, the P-wave velocity is constrained by kinematics. To avoid convergence in local minima, we use a global optimization scheme. The inversion is not angle limited by NMO stretch and linearization of the Zoeppritz equation; thus, we can use data up to refraction energy. This inversion approach requires many iterations and is, therefore, computer-intensive — different solutions can be used to overcome it. For post-stack inversion, when estimating acoustic impedance, the approach requires N iterations (n computations). For pre-stack inversion of an offset gather with K traces, also a factor F for calculation of the kinematics implies. Then searching for Vp, Vs, and Dn, the approach requires approximate N^3 iterations (f*k*n^3). We decrease the number of computations by choosing a hybrid scheme. First, we do a two-parameter search for Vp and Dn. Then, as an example, we fix a Vp parameter and perform a two-parameter search for Vs and Dn. This scheme could be repeated j times differently, reducing the computation cost to j*f*k*n^2. We demonstrate that this approach yields benefits in the rock properties estimation from seismic data.

The computation scheme for AI-driven inversion