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Inversion of crosshole traveltimes using particle swarm optimization

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Crosshole tomography based on the inversion of seismic or ground-penetrating radar traveltimes has proven to be a robust geophysical exploration technique in many near-surface applications. Usually, linearized inversion techniques are employed to reconstruct the velocity field from the measured traveltimes. As an alternative we propose a global optimization approach based on particle swarm optimization (PSO). PSO is a population based stochastic optimization method inspired by the social behavior of bird flocking and fish schooling. Although it has shown to provide excellent convergence rates compared to other more common global optimization approaches (such as those based on different variants of simulated annealing or genetic algorithms), the PSO approach has been largely ignored by the geophysical community so far.
In this presentation, we show the applicability and flexibility of a PSO based inversion strategy to reconstruct 2D velocity fields from crosshole traveltime data sets. The potential of our strategy is demonstrated using synthetic and field data examples and by comparing our PSO inversion results to smooth models found by a standard linearized inversion approach. Our results demonstrate that PSO is an efficient global optimization algorithm able to address typical crosshole tomographic applications. In addition, we may use target-oriented model parameterizations, which, compared to standard cell-based parameterizations, allows for significantly reducing the number of unknown model parameters and for efficiently implementing a priori model constraints. A further benefit of our inversion strategy is its ability to generate a representative ensemble of acceptable models. Analyzing such an ensemble allows to appraise uncertainty, resolution, and non-uniqueness issues, respectively, in a straightforward and understandable manner. As PSO inversion strategies are easy to implement and, from our experience, need less parameter adjustments and provide faster convergence rates compared to other global optimization approaches (e.g., very fast simulated annealing), we believe that PSO is a well suited global optimization strategy to invert a variety of geophysical data.