ABSTRACT

Seismic transmission tomography provides a means of direct estimation of subsurface velocity distribution using first arrival traveltimes from cross-hole data. With the increasing demand for high resolution subsurface imaging for foundation and geotechnical investigations and exploration seismology, transmission tomography has become an important geophysical tool. The existing tomographic interpretation methods namely SIRT, ART and CGT are calculus-based enumerative techniques wherein the subsurface region between the boreholes is decomposed into a number of tiny constant velocity cells. The inversion is actually performed on the time derivative matrix. But these methods fail to resolve discontinuities in the velocity/slowness distribution most of the times.

Conventional ray-tracing techniques and inversion algorithms encounter many difficulties when applied to tomographic analysis, for example,

i) head waves are not generally included,

ii) a single raypath is usually assumed for each source-receiver pair,

iii) large computation time is required for many source-receiver pairs,

and iv) it is difficult to find a raypath in a complicated velocity distribution.

To overcome these problems a completely new ray-tracing algorithm is developed using the reciprocity principle and dynamic programming approach. This robust forward calculation routine is used in the implementation of cross-hole seismic tomographic application presented here. Initially, the performance of SIRT and back projection schemes coded as a part of this investigation is tested on a few typical seismic cross-hole geometries. These conventional methods usually suffer from the risk of generating spurious images of the subsurface.

The growing need for higher resolution has drawn us into the search for an interpretation technique to image the subsurface using model-free estimators. This search led us to the field of pattern recognition called neural networks. The widely used back propagation paradigm is tested for training a three-layer network. In this process there is every possibility of getting trapped in local minima for very small step sizes. Also this requires training using a large volume of patterns. Since the cross-hole

seismic tomographic imaging can be considered to be a problem of approximation of a function i.e., mapping of traveltime vector to the velocity / slowness vector, this falls under the perview of pattern classification problem. We, therefore, implemented forward-only counter propagation neural network in the present tomographic formulation. The results presented here show the effectiveness of this algorithm. But the inherent limitation of neural networks lies in the requirement of exhaustive training for the routine interpretation.

Since finding the optimal solution starting with even poor initial models is the final goal, the global optimization and search techniques like simulated evolution, can be applied in the implementation of our tomographic formulation. Compared to traditional methods such as analytical and enumerative strategies, the simulated evolution is robust, global and generally more straight forward to apply. Natural evolution is a population-based optimization process. Simulating this process on a computer results in stochastic optimization techniques that can often outperform classical methods of optimization when applied to difficult real-world problems like imaging the complex subsurface structure of the earth. Genetic algorithms, evolution strategies and evolutionary programming are the main avenues of research in the simulated evolution algorithm. Genetic algorithms stress chromosomal operators. Evolution strategies emphasize behavioral changes at the level of the individual while evolutionary programming stresses behavioral changes at the level of the species. The present work embodies the results obtained by GA and EP schemes implemented in this investigation to tackle the tomographic solutions. What transpires in the present work on simulated evolution is the introduction of a new genetic operator called '*Region-growing mutation*' to speed up the search process. Highly encouraging results are obtained when these programs are tested on a varied range of synthetic geological models namely, detection of voids in coal seams, subsurface faulted layers, vertical dyke etc., in smaller and larger grids. Since EP does not use the crossover operation, it may result in a more diverse population than a single GA run, which may be very useful in the tomographic scanning of the subsurface. The strength of our simulated evolution approaches lies in the fact that they start with a highly random assumption without any a priori structural information but still can guide the process to the exact solution. This undoubtedly opens an avenue of research in geophysical tomography and our investigation is an attempt in that direction.

Key Words : Medical tomography, cross-hole, transmission, reflection, diffraction tomography, forward modeling, ART, SIRT, CGT, RAYPT, CDI, back projection, slowness/velocity matrix, traveltime vector, Fourier transform, Filtered back projection, matrix inversion, ray-tracing, raypath, finite difference, eikonal equation, Hyperbolic conservation law, Graph theory, Acoustic reciprocity principle, Fermat's principle, linear interpolation, non-linear interpolation, dynamic programming, iterative reconstruction, SVD, DLSQR, neural networks, supervised learning, unsupervised learning, feed forward network, feedback network, back-propagation neural network, forward-only counter propagation neural network, competitive layer, Kohonen layer, Grossberg layer, winner, training, weights, learning rates, void, coal seam, subsurface fault, dyke, sill, simulated evolution, genetic algorithm, simulated annealing, evolutionary programming, global optimization, crossover, crossover rate, mutation, mutation rate, region-growing mutation, coding, selection, fitness function, Gaussian distribution, step function, population, schemata, building block, Schema theorem, Building block hypothesis, convergence.