PAPER D

AN APPROACH TO ADAPTIVE GRIDDING FOR TRAVELTIME TOMOGRAPHY

Jerry M. Harris

ABSTRACT

This short paper summarizes the recent development and application of a node-based tomography inversion algorithm. The node model provides adaptive gridding to address the problems of non-uniform ray coverage and inhomogeneous resolution. The spacing or density of nodes are adaptively selected to provide more uniform ray density per node or to match the geometrical pattern of the geological structure being imaged. In this way, reconstruction artifacts associated with non-uniform coverage may be reduced while velocity estimates are made more reliably. Also, "unknowns' are not wasted on homogeneous zones but may be concentrated in heterogeneous regions of the image. If no information is available to adapt the grid, the node model may be run as a regular spaced lattice.

THE MODEL

The motivation for this model was introduced last year (Harris, 1993). Consider velocity inversion from traveltime data. For the forward problem, the velocity is specified at irregularly spaced nodes. See Figure 1. The forward model traveltime is obtained from the discrete summation:

$$t_j = \sum_{m=1}^{M_j} \hat{S}_{jm} \Delta\ell \tag{1}$$

where $\hat{S}_{jm}$ are "interpolated" slowness values for points along the jth ray path and M_j is the number of equi-spaced steps of length $\Delta\ell$ along the ray. The slowness values $\hat{S}_{jm}$ are interpolated from the nodes using an N-term interpolation scheme:

$$\hat{S}_{jm} = \sum_{i=1}^{N} d_{ijm} S_i , \tag{2}$$

where the S_i's are the values of slowness at the N nodes of the model and the d_{ijm}'s are the interpolation coefficients. In practice, I use bi-linear interpolation from the four nearest nodes, i.e, N=4. The interpolation coefficients are determined in closed form following identification of the locations of the four surrounding nodes. See Figure 2.

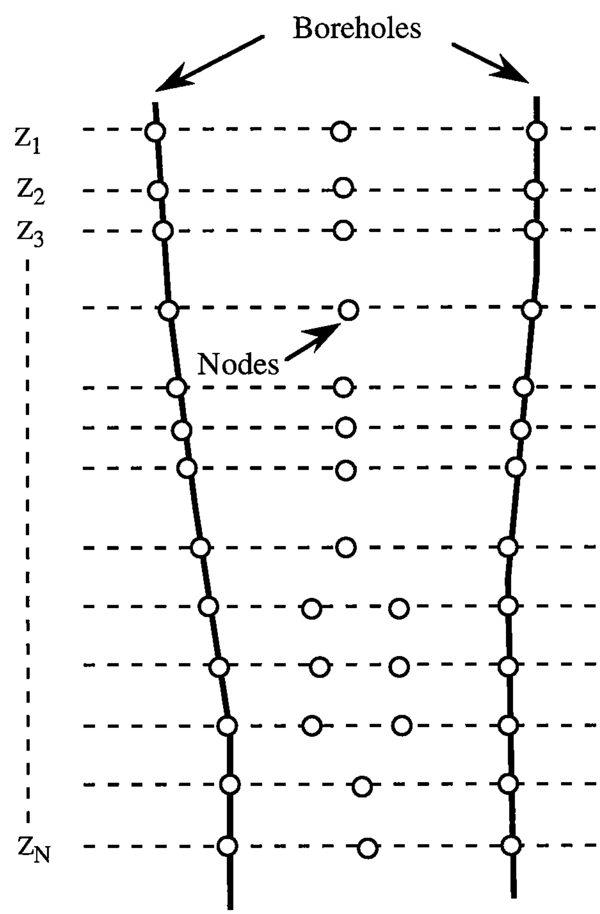

Figure 1. The density and pattern of nodes are adapted by the user to fit the geological structure or other criteria such as ray density. The location of the nodes is given by its depth and offset coordinates. For many geological situations, its is appropriate to begin with nodes only along the profile of the wellbores.

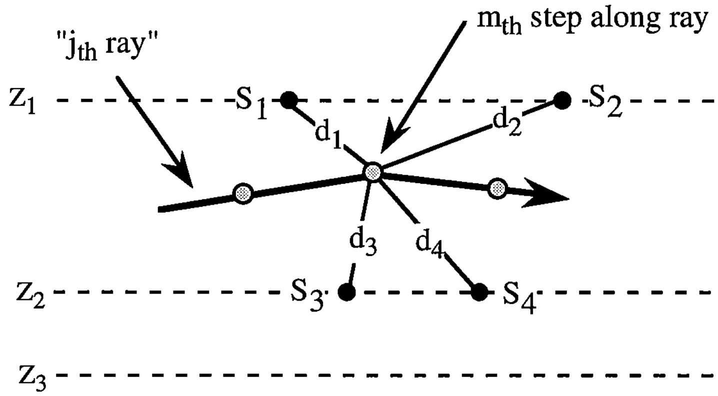

Figure 2. Slowness along the ray path is calculated by interpolating values from the four neighboring nodes. When node spacing is small and uniform, i.e., a lattice, a nearest neighbor approximation can be used and the node model reduces to the string model.

Because the nodes are irregularly spaced, computer time is spent finding the four nodes surrounding the interpolation point. This effort can be reduced when the nodes are regularly spaced and can be indexed for a fast search. During forward modeling, the slowness is known and the bi-linear coefficients are used to calculate the slowness at the interpolation point. During inversion, for example using SIRT, the bi-linear coefficients are used to weight the distribution of traveltime residual to the four contributing nodes.

EXAMPLES

The first example is the synthetic model shown in Fig. 3a. This model is mostly 1-D with a dipping feature near the bottom of the survey. The result of a SIRT inversion using straight rays is shown in Fig. 3b. Fig. 3b was then used as the background for the curved ray result shown in Fig. 3c. These results were obtained for two nodes per depth level. The two nodes are located along the right and left boundaries of the model at uniform depth intervals.

The second example, Figs. 4a through 4c, uses real field data taken from a Gulf Coast site. This result illustrates how complex interwell variations are handled by only two lateral nodes.

REFERENCES

Harris, J. M., 1993. Lattice parameterization for tomography, STP Annual Rpt, vol. 4, no.1, Paper E.