TWO–POINT RAY TRACING IN 3-D HETEROGENEOUS BLOCK STRUCTURES

Petr Bulant & **Luděk Klimeš**
Department of Geophysics, Charles University, Ke Karlovu 3, 121 16 Praha 2, Czech Republic.

Abstract submitted for presentation at the 58th EAGE meeting, Amsterdam, 3–7 June 1996.

The *shooting method* is based on iterative application of an *initial–value ray tracing* algorithm. The presented versions of the shooting algorithm have been proposed for two–point ray tracing in considerably general 3-D models of heterogeneous geological structures. In each computation, only the rays of a single *elementary wave*, i.e. the rays whose behaviour at structural interfaces is prescribed by a priori information called the *ray code*, are considered. The rays are thus specified uniquely by the *ray take–off parameters*. For each given ray code, the principal problem of two–point ray tracing in heterogeneous block models then consists in a sufficiently accurate determination of boundaries between rays with different *ray histories*, i.e. passing through different geological blocks, across different structural interfaces, terminated in different areas for different reasons, or passing through a different number of caustics. The demarcation belts between the different ray histories, corresponding to numerical uncertainty of the boundaries between the ray histories, have to be kept reasonably narrow, because all two–point rays, situated inside the demarcation belts, will be lost. As soon as the 2-D *domain of ray take–off parameters* is decomposed, with given accuracy, into *homogeneous subdomains* corresponding to rays of equal ray histories, the two–point rays can be found (using, e.g., the paraxial ray approximation) within individual homogeneous subdomains.

The shooting algorithm, above all based on the procedures to demarcate boundaries between different ray histories, is thus closely related to *controlled initial–value ray tracing*, whose aim is not to hit given receivers, but to cover the model with a sufficiently dense system of rays (or to cover the reference surface with a sufficiently dense system of ray endpoints). The demarcation of ray histories and the triangularization of homogeneous subdomains corresponding to rays of equal ray histories play the principal role in controlled initial–value ray tracing. In this way the space between two consecutive wavefronts is decomposed into *ray cells*, as in the *wavefront tracing method* (Vinje, Iversen & Gjøystdal, 1993; Vinje, Iversen, Gjøystdal & Åstebøl, 1996), and the travel times and all other calculated quantities may routinely be interpolated within individual ray cells. Unlike *weighting of paraxial ray approximations*, this method is capable to strictly comply with the boundaries of shadow zones. Controlled initial–value ray tracing, basically equivalent to wavefront tracing, is thus very promising tool of fast calculation of most energetic *elementary travel times* at gridpoints of dense rectangular grids of points for, e.g., ray–theory based migration techniques or nonlinear determination of seismic hypocentres.

The shooting algorithm is, to some extent, independent of an initial–value ray tracer. "To some extent" means that the ray tracer has to provide the shooting algorithm with required information on traced rays. The algorithm is also independent of initial conditions for rays: the boundary–value rays corresponding to a wavefront of general curvature incident at the bottom or sides of the model, to exploding reflector or edge diffractor are sought in the same way as two–point rays leaving a single point source.

The corresponding Fortran 77 computer code for 3-D two point–ray tracing is being developed on the basis of package `MODEL` to specify *smooth block models* of geological structures, and package `CRT` for initial–value ray tracing in such models (Červený, Klimeš & Pšenčík, 1988). The model specification has been proposed in the way enabling the application of a broadest variety of travel–time and full–wavefield modelling techniques. A smooth block model is composed of blocks of arbitrary shapes, separated by structural interfaces covered by a finite number of smooth surfaces. Inside each block, the material parameters, like P and S wave velocities, are smooth functions of spatial coordinates. The method usually enables to find all two-point rays, even for weakly refracted rays. For more details refer to Bulant (1996).

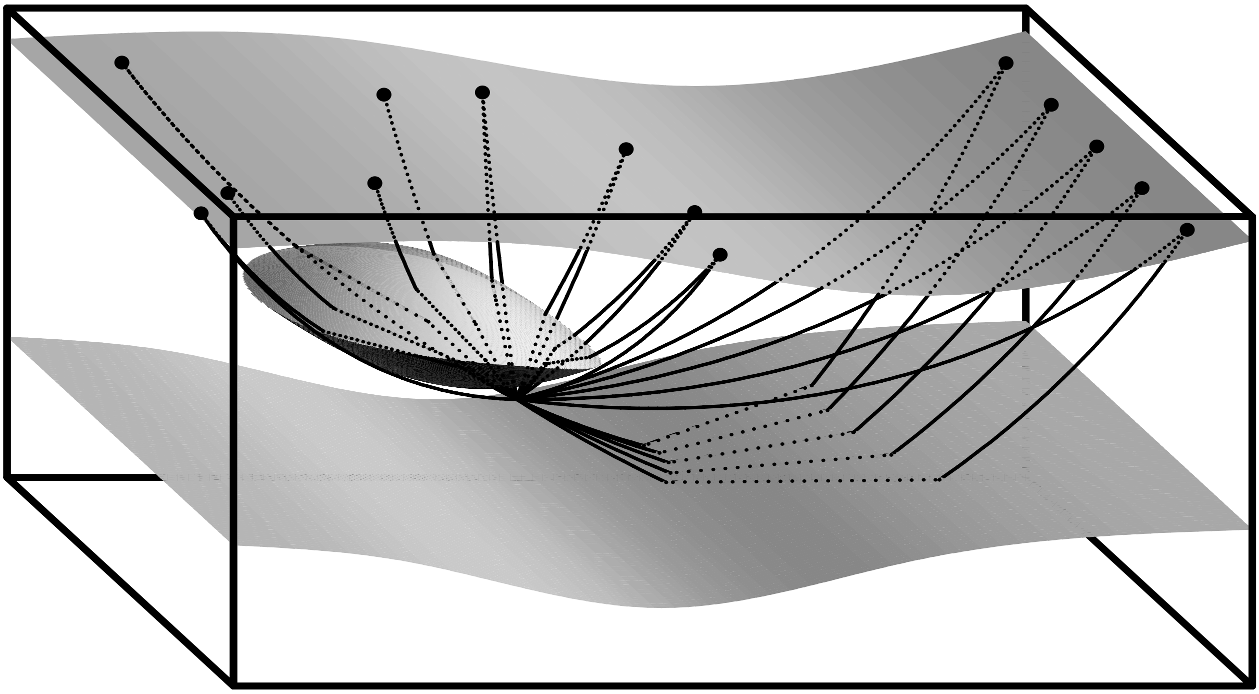

Figure 1. Two–point refracted rays in a simple artificial model with a homogeneous lenticular inclusion embedded in a layer of a constant velocity gradient. The receivers are specified along the curved Earth surface.

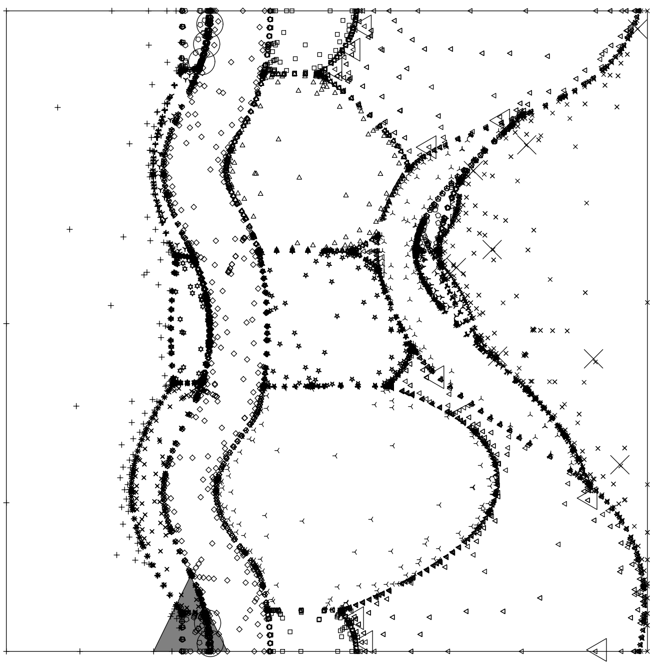

Figure 2. Take–off parameters of all rays traced in the model with a lenticular inclusion (Figure 1) in order to find refracted two–point rays. Rays of different ray histories are denoted by different marks. The two–point rays are emphasized by considerably enlarged marks. Enlarged detail of the shaded triangle is shown in Figure 2.

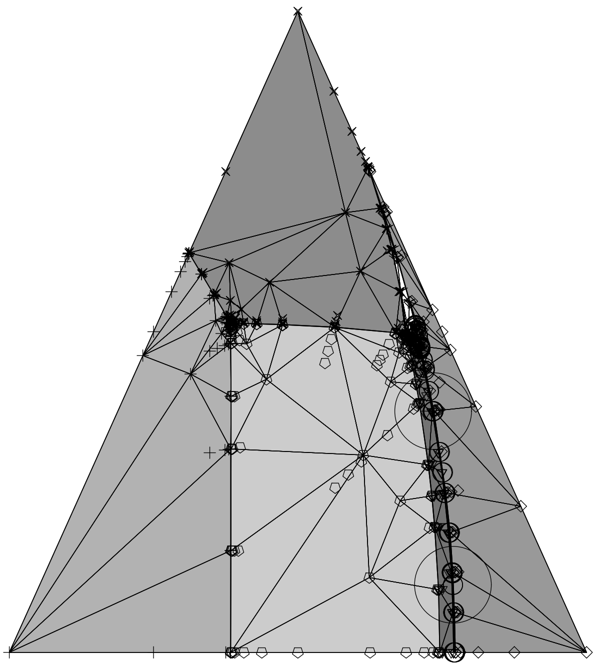

Figure 3. There are 7 different ray histories in this triangle, distinguished by different marks and shading. The history corresponding to rays refracted in the bottom layer and incident at the Earth surface (circle marks) includes two–point rays. The history forms a very narrow strip situated between the narrow strip ($\bigtriangledown$ marks) and the rightmost homogeneous subdomain (diamonds).

References

Bulant, P. (1996): Two–point ray tracing in 3-D. PAGEOPH, in press.

Červený, V., Klimeš, L. & Pšenčík, I. (1988): Complete seismic–ray tracing in three–dimensional structures. In: Doornbos, D.J. (ed.), Seismological Algorithms, pp. 89–168. Academic Press, New York.

Vinje, V., Iversen, E. & Gjøystdal, H. (1993): Traveltime and amplitude estimation using wavefront construction. Geophysics, **58**, 1157–1166.

Vinje, V., Iversen, E., Gjøystdal, H. & Åstebøl, K. (1996): Estimation of multivalued arrivals in 3D models using wavefront construction. Geophys. Prospecting, submitted.