

Abstract

In this thesis, I propose several methods for an efficient computation of 2D and 3D traveltimes of transmitted waves in smooth media. Traveltimes are needed in several seismic processing methods such as Kirchhoff prestack and poststack migration, migration velocity analysis, Kirchhoff modelling, or traveltime tomography. The greatest number of traveltimes are needed by 3D prestack Kirchhoff depth migration (PKDM). Despite the continuous increase in computing capacities, the computation of traveltimes for 3D PKDM is still a challenge.

Since the wavefront is usually folded, the same wave may arrive at a subsurface point more than one time, i.e., we have multivalued traveltimes. For efficient computation of multivalued traveltimes in 3D heterogeneous media, I implement a modified 3D wavefront construction (WFC) method, a hybrid method which combines a 3D finite-difference eikonal solver (FDES) with the 3D WFC method, and I develop the wavefront-oriented ray-tracing (WRT) technique (2D and 3D version).

The WFC method starts at the source with few rays which are propagated stepwise through a smooth velocity model. The ray field is examined at each wavefront and a new ray is interpolated between two adjacent rays if certain criteria are satisfied. The traveltimes computed along the rays are used for the estimation of traveltimes on a rectangular grid. This estimation is carried out within a 3D cell, i.e., a region bounded by two consecutive wavefronts and three rays.

This WFC method can be used as a stand-alone method for the computation of multivalued traveltimes or can be combined with a FDES to a hybrid method. The FDES-WFC hybrid method computes the first arrivals by the FDES and the later arrivals by the WFC method.

The WRT technique is related to the WFC methods, but in contrast to the latter the WRT technique inserts a new ray by tracing it directly from the source. This is an approach of higher accuracy than the insertion of a new ray by interpolation on (or near) the wavefront. There are also other differences between WFC methods and the WRT technique. The 3D WRT technique applies a new set of insertion criteria which allows a better control of the ray density. To estimate the traveltimes at gridpoints in the WRT technique, I propose a new approach, which I call the distance-weighted averaging of extrapolated traveltimes.