Wave Inversion Technology, Report No. 2, pages 47-50

Derivation and Implementation of the Seismic Image Wave Theory and its Application to Seismic Reflection Data

Jürgen Mann[1]

keywords: *imaging, image waves, migration*

ABSTRACT

Results of imaging methods like migration depend on estimated parameters like the velocity model which have to be determined iteratively to obtain appropriate images. In my diploma thesis summarized below I deal with a new approach to calculate updated images for new parameter values without the need to perform the entire imaging process over and over again. The approach is based on the description of imaging methods as generalized wave propagation phenomena.

SUMMARY

This thesis is concerned with the derivation, implementation and application of the seismic image wave theory by Hubral et al. (1996b). In this theory, well-known imaging problems are taken as wave propagation phenomena with appropriate propagation variables. The theory is partly generalized to 3D in this thesis. The seismic image wave theory is based on the method of discontinuities by Goldin (1989, 1990).

Based on straightforward geometrical approaches, image wave equations are derived for four different imaging problems: post-stack remigration in the time domain, post-stack remigration in the depth domain, migration to zero-offset (MZO, and dip moveout (DMO). The latter two problems are self-explanatory and are also called configuration transforms by Hubral et al. (1996a) and Tygel et al. (1996). Post-stack remigration means transforming images migrated with a (possibly wrong) velocity model to a new image corresponding to another (updated) velocity model.

In the present thesis, the derivations are restricted to constant velocity models and the kinematical aspects of the imaging problems. The basic idea is to chain migration and demigration methods to obtain so-called Huygens image waves for the respective

---

[1] **email:** jmann@gpirs1.physik.uni-karlsruhe.de

imaging problem. This is closely related to the unified approach to 3D seismic reflection imaging by Hubral et al. (1996a) and Tygel et al. (1996), where Kirchhoff-type operators are introduced for the mentioned imaging problems.

Using the Huygens image waves, corresponding image wave eikonal equations are derived. I propose four seismic image wave equations which can be shown to yield the mentioned image wave eikonal equations by using ansatzes similar to the well-known zero-order ray approximation. While the proposed MZO and DMO image wave equations are restricted to 2D and were already presented by Hubral et al. (1996b), the image wave equations for the remigration problems are generalized to 3D.

The imaging problems may now be reformulated as initial value problems (IVP). In the framework of this thesis, these IVP are solved by using semi-explicit finite difference (FD) schemes. The FD schemes and some additional features are implemented and provide the following range of possibilities:

- 2D and 3D remigration in the time and depth domain applied towards higher or lower velocities.
- Normal moveout for constant velocity models.
- DMO and MZO for an arbitrary number of common-offset gathers.
- Stacking of DMO or MZO results.

The FD schemes are applied to various synthetic and real data sets. Apart from the MZO, which has not yet produced useful results, all imaging problems are successfully solved by this implementation. In particular the remigration in the time domain and the DMO proved very stable.

These methods allow one to see the seismic images propagating through the respective domain when changing the respective propagation variable, i. e. offset or velocity. Thus the sensitivity of the images to parameter changes may be observed. Please note that the propagation takes place in fictitious domains and does not correspond to any physical propagation processes. For obvious reasons, these methods are also called velocity and offset continuation, respectively.

With remigration, the best image can be selected out of a sequence of many by observing the changes of significant structures in the images, like bow ties or diffraction patterns. Structures of this kind are used to determine an optimum constant migration velocity, i. e. to obtain information on the macro velocity model. Although derived for a constant velocity model, remigration in the time domain also proves applicable to weakly inhomogeneous models with certain restrictions, as is shown for the Marmousi 3D overthrust model.

As remigration in time domain accepts (simulated) zero-offset data associated with the migration velocity $v = 0$, the implemented methods may be chained in order to obtain time-migrated images from pre-stack data by subsequently using NMO, DMO, stack and remigration in the time domain.

The complete translation into English as well as the original version of the thesis in German is available under
`http://www.uni-karlsruhe.de/~nf25/diplom/diplom.html`

REFERENCES

Goldin, S. V., 1989, Method of discontinuities and theoretical problems of migration: 59th Annual Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 1326.

Goldin, S. V., A geometrical approach to seismic processing: The method of discontinuities:, Technical Report 67, Stanford Exploration Project, 1990.

Hubral, P., Schleicher, J., and Tygel, M., 1996a, A unified approach to 3-D seismic reflection imaging, Part I: Basic concepts: Geophysics, **61**, no. 3, 742–758.

Hubral, P., Tygel, M., and Schleicher, J., 1996b, Seismic image waves: Geophys. Journ. Intern., **125**, 431–442.

Mann, J., and Jaya, M. S., 1997a, 3D finite-difference post-stack time and depth remigration: 59th Mtg. Eur. Assoc. Expl. Geophys., Extended Abstracts.

Mann, J., and Jaya, M. S., 1997b, Zeit- und Tiefenremigration in homogenen Geschwindigkeitsmodellen: Neuimplementierung und Anwendung auf synthetische Zero-Offset-Datensätze: 57. Jahrestagung d. Deut. Geophys. Ges., Abstracts.

Mann, J., 1997, Herleitung und Implementierung der Seismic-Image-Wave-Theorie und Anwendung auf reflexionsseismische Messdaten: Master's thesis, Geophysikalisches Institut der Universität Karlsruhe.

Tygel, M., Schleicher, J., and Hubral, P., 1996, A unified approach to 3-D seismic reflection imaging, Part II: Theory: Geophysics, **61**, no. 3, 759–775.