Introduction. Post–stack remigration based on seismic image–wave theory has been implemented with a refined finite–difference (FD) scheme. Remigration can be performed in depth as well as in time domain. Post-stack constant–velocity migrated sections in the appropriate domain serve as input data. Zero offset (ZO) sections or common–mid–point (CMP) stack sections may be considered as time–migrated sections for migration velocity zero. Remigration was applied to various 2D synthetic and real data sets and a 3D ZO section of the Marmousi overthrust model.

Seismic image waves. Similar to the common scalar wave–equation, the so called image wave–equations (Hubral et al., 1996) describe a kind of propagation of imaged seismic reflectors in a fictitious image space. Generalized to 3D, these equations are given by partial differential equations (PDE)

$$4\frac{\partial^2}{\partial v \partial t} p(x,y,t,v) + vt\,\tilde{\nabla}^2 p(x,y,t,v) = 0 \tag{1}$$

$$\tilde{\nabla}^2 p(x,y,z,v) + \frac{\partial^2}{\partial z^2} p(x,y,z,v) + \frac{v}{z}\frac{\partial^2}{\partial v \partial z} p(x,y,z,v) = 0\ . \tag{2}$$

Eq. (1) refers to time domain, eq. (2) to depth domain, $\tilde{\nabla}^2 = \frac{\partial^2}{\partial x^2}$ in 2D, $\tilde{\nabla}^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$ in 3D, resp. In the 4D (x,y,t,v) or (x,y,z,v) image space, each slice $v = const$ represents a migrated 3D image cube.

Implementation. The corresponding initial value problems $p(x,y,t,v_0) \rightarrow p(x,y,t,v)$ in time and $p(x,y,z,v_0) \rightarrow p(x,y,z,v)$ in depth domain are solved with semi–explicit FD schemes. Eq. (3) exemplarily shows one of the used schemes in time domain for $v_0 < v$. The actually used FD scheme depends on the direction of propagation and the demanded accuracy of the derivation operators. Boundary values were handled due to the zero slope condition.

$$\begin{aligned} p^{l+1}_{i,j,k} &= \frac{t\,\Delta t\, v\, \Delta v}{48}\left[\frac{16\left(p^l_{i,j-1,k} + p^l_{i,j+1,k}\right) - p^l_{i,j-2,k} - p^l_{i,j+2,k} - 30\,p^l_{i,j,k}}{\Delta x^2} + \right. \\ &\left. + \frac{16\left(p^l_{i,j,k-1} + p^l_{i,j,k+1}\right) - p^l_{i,j,k-2} - p^l_{i,j,k+2} - 30\,p^l_{i,j,k}}{\Delta y^2}\right] + p^{l+1}_{i+1,j,k} - p^l_{i+1,j,k} + p^l_{i,j,k} \end{aligned} \tag{3}$$

The index i denotes time, j and k offsets in x– and y–direction, resp., l velocity. Δx, Δy, Δt and Δv are the intervals in the respective direction. For forward propagation ($\Delta v > 0$), time has to be decreased in the actual calculation to achieve a stable process, and vice versa for backward propagation ($\Delta v < 0$).

Application. In order to test the intrinsic consistency of this method synthetic post–stack sections for constant velocity models were used. Figure 1a shows one of these sections. Figure 1b shows a snapshot ($v = 5$ km/s) of the remigration result generated by forward propagating the migrated image from $v = 0$ km/s to $v = 6$ km/s. Finally, figure 1c shows a pseudo–ZO section generated by backward propagating the previously remigrated image from $v = 6$ km/s to $v = 0$ km/s. The result

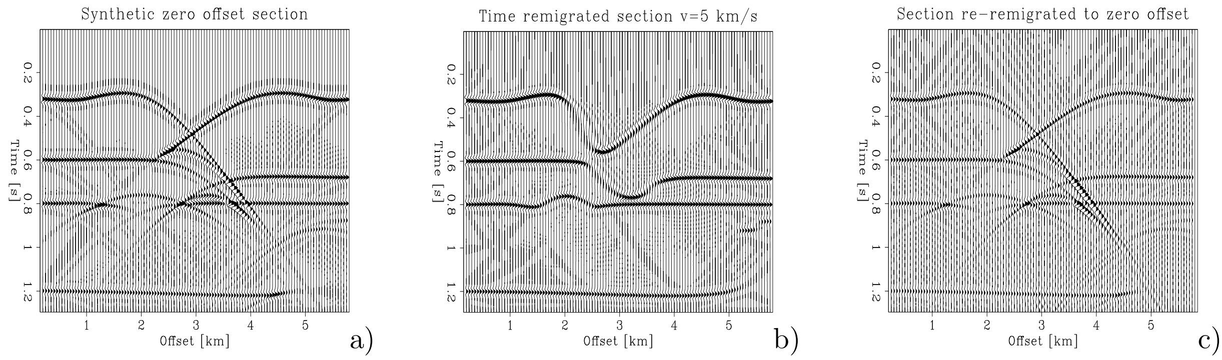

Figure 1: Synthetic data set $v = 5$ km/s: a) ZO section, b) time remigrated section for $v = 5$ km/s, c) pseudo–ZO section.

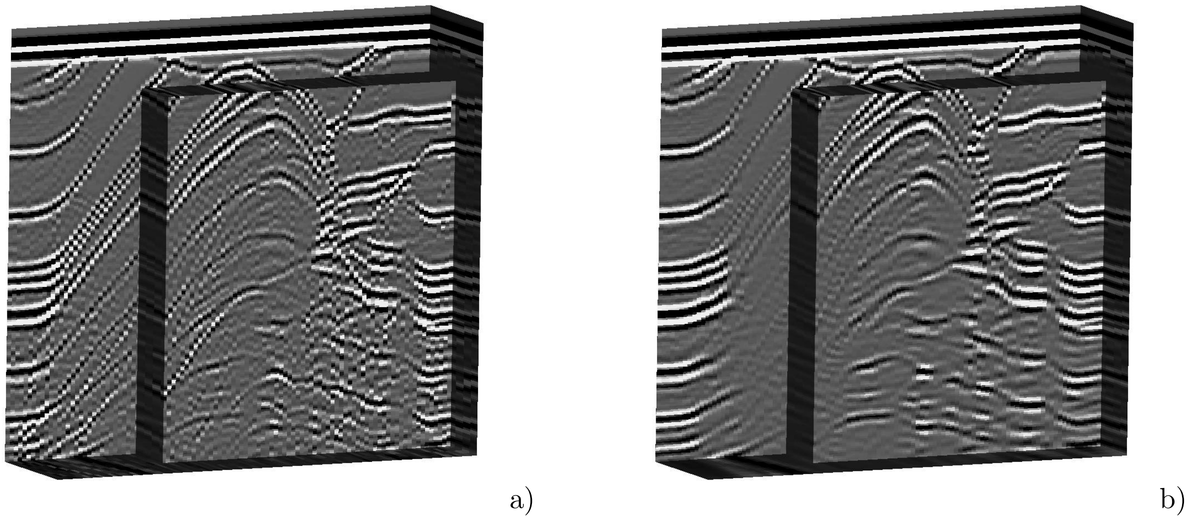

Figure 2: Marmousi 3D overthrust model: a) clipping of the zero offset section, b) time remigrated section for $v = 2400$ m/s.

for the Marmousi 3D overthrust model is shown in Figure 2. Since the underlying velocity model is quite inhomogeneous, the method fails to image deep reflectors with complex overburden. FD remigration was also applied to a 2D time–migrated section of a real data set provided by DMT in Bochum, Germany.

Conclusions. FD time– and depth–remigration based on image–wave theory can transform migrated images in the respective domain to new ones for a continuum of constant velocities. It results as a part of one and the same algorithm eq. (1) or eq. (2), resp. Post–stack sections can be time–remigrated without any preceding migration process. Demigration of time–migrated sections is feasible by backward remigration. The method implies a constant velocity model and therefore necessarily fails when applied to inhomogeneous models. As shown in the 2D real data sets, the remigration may still lead to reasonable results in weakly inhomogeneous models. In strongly inhomogeneous models, remigration may be used in an iterative process: Using remigration to estimate the velocity in the uppermost layer, updating the velocity model, performing migration with the updated velocity model and repeating these steps for all layers.

Reference

Hubral, P., Tygel, M., Schleicher, J., 1996, Seismic image waves: Geophysical Journal International, vol. 125, pp. 431-442

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