Inverse scattering internal multiple prediction on physical modeling data

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G e o C o n v e n t i o n   2 0 1 2 : V i s i o n

We have implemented a 1D version of the inverse scattering series internal multiple attenuation algorithm due to Weglein et al. (1997), and applied it to physical modeling data. Interbed multiples in land data sets can present very challenging problems for interpretation, and prediction methods of this kind may provide powerful tools for their suppression. However, it can be difficult to choose prediction parameters, such as algorithm search limits, by direct examination of field data sets. We view physical modeling environments as ideal staging grounds, within which real data from controlled targets may be analyzed to guide the choice of optimal parameters. In this paper we present early results of the application of a 1D version of the algorithm to a specially designed physical modeling data set.

Introduction

Multiple events can be mistaken for primary reflections, and may distort primary events and obscure the task of interpretation. The inverse scattering internal multiple algorithm is capable of attenuating internal multiples without any a priori information about the medium through which the waves propagate.

The application of scattering theory into seismic processing has been studied for many decades, and has provided an alternative theoretical approach to understand, describe and represent seismic the behavior of seismic waves. Basically, this theory relates a perturbation in the properties of a medium to the associated perturbation in the wave field.

In this work we will focus in the suppression of internal multiples and we will illustrate how the inverse scattering internal multiple algorithm is capable to attenuate internal multiples without any a priori information about the medium through which the waves propagate. Then, we will apply a simple 1D form of the algorithm to physical model data.

Theory and/or Method

The first term in the internal multiple attenuation series for the 1D normal incidence case is (Weglein et. al., 1997):

$$b_{3IM}(k_z) = \int_{-\infty}^{\infty} dz'_1 \, e^{k_z i \, z'_1} b_1(z'_1) . \int_{-\infty}^{z'_1 - \epsilon} dz'_2 b_1(z'_2) . e^{-ik_z z'_2} \int_{z'_2 + \epsilon}^{\infty} dz'_3 b_1(z'_3) . e^{ik_z z'_3}$$

The function $b_{3IM}(k_z)$ is a prediction of the internal multiple present in the data. It is in the domain k_z, where k_z is the conjugate of pseudo-depth ($z=c_0t/2$), hence the output can be straightforwardly transformed to the time domain. The $b_1(z)$ entries are the input data traces in pseudo-depth domain.

The inverse scattering internal multiple algorithm needs just the data itself as an input. Prior to predicting the internal multiples, the algorithm makes a series of transformations of the data: first, to frequency domain, then to vertical wave number and finally to pseudo-depth. Once the data is transform to pseudo-depth, the algorithm starts to search for possible multiples in data.

The subevents that the algorithm identifies as possible ray path parts of the internal multiples must satisfy the lower-higher-lower condition. The algorithm in fact treats the internal multiples as a combination of subevents. The value of epsilon is an important parameter in the algorithm and is related to the width of the wavelet. The key to understand how this algorithm predicts the internal multiples just with the data itself is to realize that the convolution of two subevents adds the times of these subevents and the crosscorrelation instead subtract the times. These subevents then construct the internal multiple at particular depth.

Physical Model Data

The University of Calgary possesses a Seismic Physical Modeling Facility that has been recently updated and improved. We used this facility to simulate a 2D marine seismic survey. The modeling facility consist of a six-axes positioning system using linear electric motors, arrays of small ultrasonic source and detector transducers, amplifiers, and signal digitization, see Figure1 (left panel). The transducers convert electrical energy to mechanical energy and vice versa. The transducer that acts as a receiver is sensitive to displacement normal or tangential to the contact face, converting particle displacement to electrical signals (Mahmoudian et al., 2011).

In the physical laboratory experiment a source (piezoelectric transducer) emits seismic energy into the model and the reflected wave field is recorded, Figure 1 (right panel). The basic assumption supporting the physical modeling approach is that seismic waves propagate identically in both settings: scaled physical model and field scenario (Ebrom and MacDonald, 1994).

Physical modeling facilitates the understanding of wave propagation in elastic models and anisotropic models. Since in the physical model experiments geometries and physical properties are well known, comparison between numerical model and field data is plausible and well performed, as well as for testing of processing, imaging, and modeling algorithms (Lawton et al.,1998).

The main objective of the utilization of physical model was to obtain high quality low noise seismic data, with clear and strong primaries and, internal multiples in order to test internal multiple attenuation algorithm. We conducted a 2D common-offset seismic survey, with 401 traces at a spacing of 10m (field scale). The source and the receiver were slightly immersed in the water. The frequencies emitted varying between 5 to 100Hz (field scaled) (Hrabi, 1994).
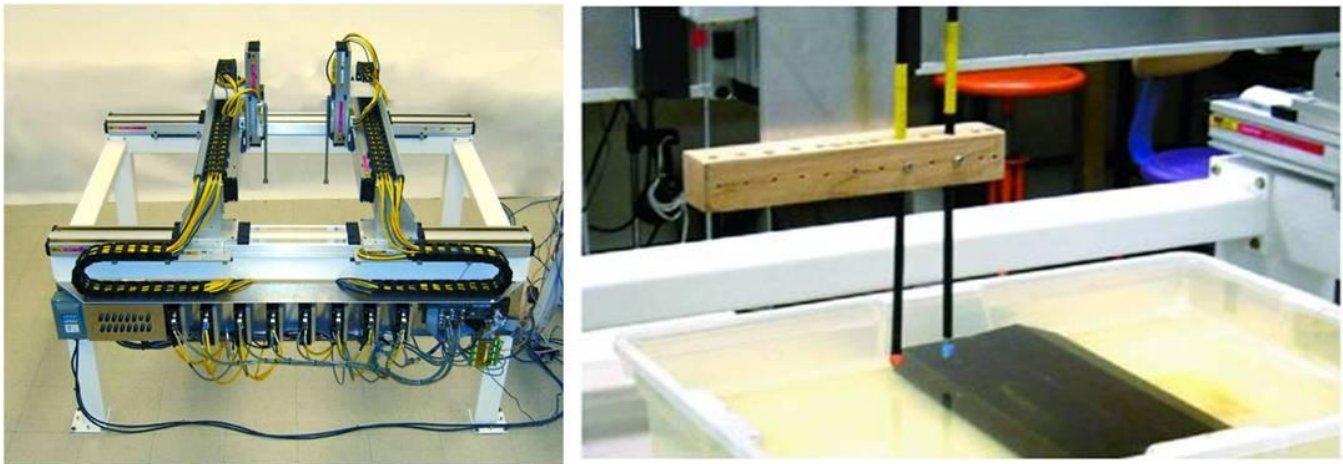
Figure 1: The left panel is 3D positioning system. The right panel shows a pair of transducers simulating a source and receiver array immersed in water pointed out the model.

The model used in this study consisted of a PVC slab, Plexiglass, smaller Aluminum slab, Plexiglass immerse in water, Figure 2 shows sketch of this model and its physical characteristics. The scaling used for distance in the model was 1:10000.
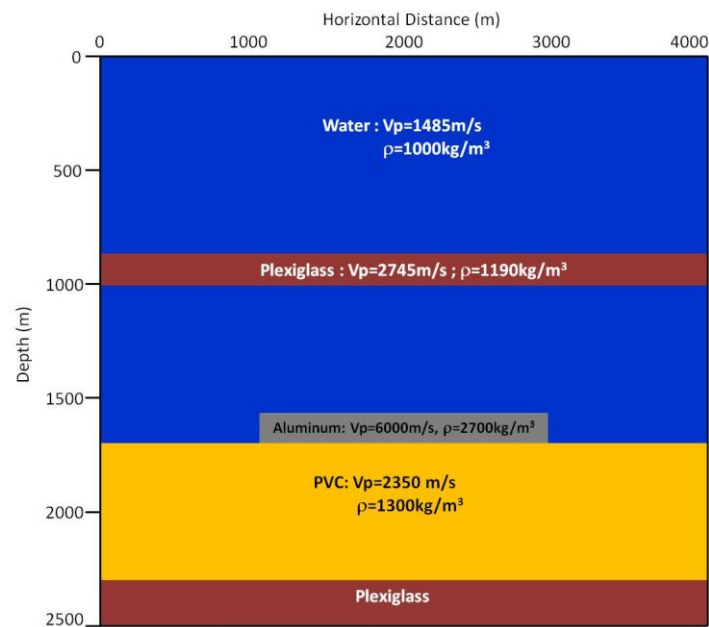

Figure 2: Schematic diagram of the model used.

The processing of the data set include: deconvolution, velocity Analysis, statics (no surface consistent) and noise attenuation filter, figure 3 (left panel).

Results

Our initial results are displayed in Figure 3. On the left panel are the (approximately) zero offset data, with the five reflections highlighted in red. These data are the input for the algorithm in equation (1). On the right the output is displayed. Using a value of epsilon (ε) of 50 sample points, internal multiples are cleanly predicted at 1.4s, 1.9s, 2.3s, 2.6s and 2.7s, as expected according to the wave velocities in the model.
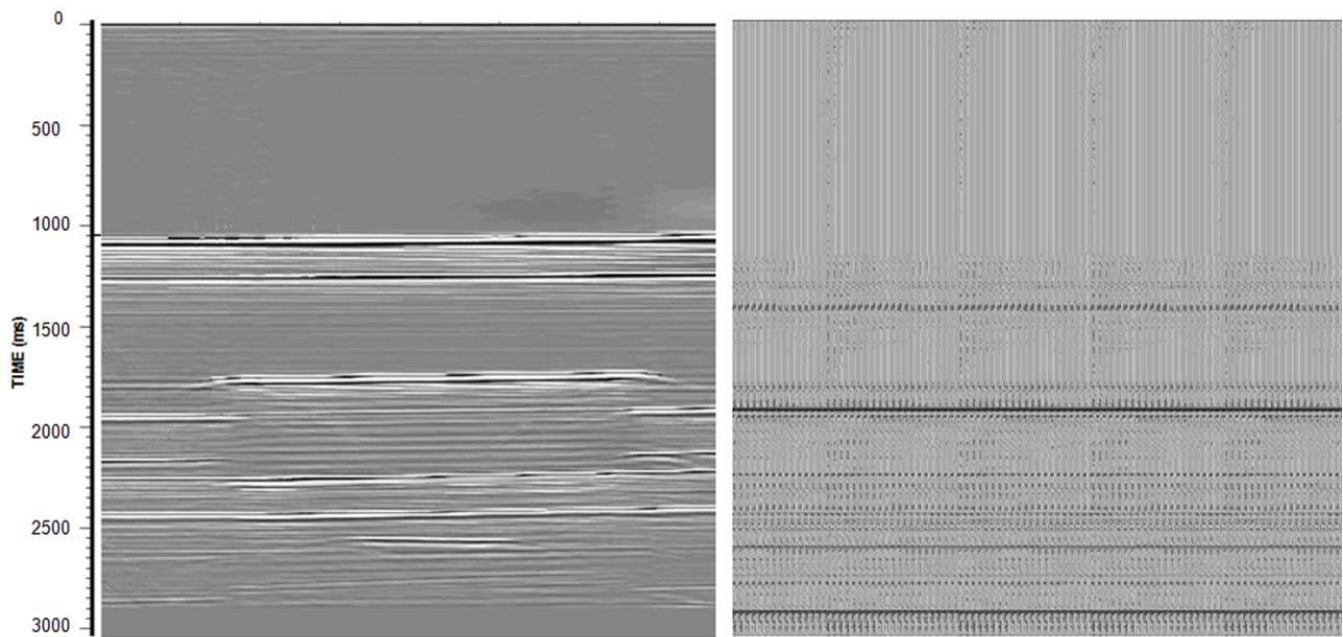
Figure 3: Left panel: common (nearly zero) offset gather and algorithm input. Right panel: internal multiple predictions.

Conclusions

In this work we implemented an inverse scattering internal multiple attenuation algorithm in physical model data. We conducted 2D common offset seismic survey; the experiment was carried out in physical model lab of the University of Calgary. Pre-processing (e.g. statics, velocity analysis, deconvolution, filtering) of the data was required. The algorithm produces clean predictions of the expected multiples, and permits systematic study of optimum parameters such as epsilon (ε).

Acknowledgements

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