Internal multiple attenuation based on inverse scattering II: implementation in physical model seismic data

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ABSTRACT

Multiple reflections represent a serious problem in the field of seismic processing. Multiple events can be mistaken for primary reflections, and may distort primary events and obscure the task of interpretation. In this work, we will focus in the suppression of internal multiples and we will illustrate how the inverse scattering internal multiple algorithm introduced by Weglein and Araujo in 1994, is able to attenuate internal multiples without any a priori information about the medium through which the waves propagate. One of the advantages of this method over others is its ability to suppress multiples that interfere with primaries without attenuating the primaries themselves. We consider the version of the algorithm for 1D normal incidence. This algorithm predicts internal multiples from other events in the data by performing a convolution and a crosscorrelation of prestack data. In this work we studied physical modeled data and found that algorithm works satisfactorily, predicting multiples with the correct time and the amplitude is reasonably similar.

INTRODUCTION

Although multiple reflections have been studied extensively, they continue to be a serious problem in the field of seismic processing. 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. Previously, we explained the theory behind this method and how it works in synthetic data (Hernandez and Innanen, 2011). In this work, we will apply a simple 1D form of the algorithm to field data from physical model seismic data set.

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 algorith 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.

The output of the algorithm is a prestack data set that contains the predicted multiples. Then, by subtracting this second data set from the original input data, the multiples are attenuated or, in the best case, removed whilst the primaries remain undamaged (Matson et al., 1999).

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 behaviour of seismic waves. Basically, this theory relates a perturbation in the properties of a medium to the associated perturbation in the wave field. The first term in the internal multiple attenuation series for the 1D normal incidence case is (Araujo et al., 1994):

$$b_{3IM}(k_z) = \int_{-\infty}^{\infty} dz_1' e^{k_z i z_1'} b_1(z_1') \int_{\infty}^{z_1'-\epsilon} dz_2' b_1(z_2') e^{-k_z i z_2'} \int_{z_2'+\epsilon}^{\infty} dz_3' b_1(z_3') e^{k_z i z_3'}, \tag{1}$$

The function $b_{3IM}(k_z)$ is a prediction of the internal multiple present in the data. It is in the k_z-domain, where k_z is the conjugate of pseudo-depth $(z = c_o t/2)$, 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.

It is important to keep in mind what happens when the value of ϵ is too small or big. For example, when ϵ is small, i.e., the limits of the equation 1 are wider and then as a result the algorithm take in account all the possible combinations, not only the one that satisfy the proper lower-higher-lower condition, and therefore the prediction include the primaries reflections as well. If instead, ϵ is too big, the limits of the searching is narrower, therefore nothing is detected it, and the algorithm does not find any subevent that can be combine and the prediction is practically null.

PHYSICAL SEISMIC MODEL DATA

The University of Calgary posseses a Seismic Physical Modeling Facility that has been recently updated and improved. We used this facility to simulate a 2D marine seismic survey. Themodelling 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 Figure 1. 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 (Mahmoundian et al., 2011). Regarding as a source, the transducer produces far field radiation patterns approximating normal and tangential displacement point sources (Aki and Richards, 1980). Digital data acquisition is performed by commercially available circuits boards installed in a desktop computer. Operating system used is Windows XP Professional. The movement of the transducers is automatically synchronized with the recording of the seismic signals. The transducers are positioned on the surface of water over an immersed solid target as if it was a marine survey (Wong et al., 2009), see figure 2.

The seismic parameters used in our experiment are presented in Table 1.

The model used in this study consisted of a PVC slab, Plexiglass, smaller Aluminum slab, Plexiglass immerse in Water, Figure 3 shows sketch of this model and its physical characteristics. The scaling used for for distance in the model was 1:10000, therefore , 1cm long by 2.5cm deep model represented 100m in horizontal distance and 250m in depth. The

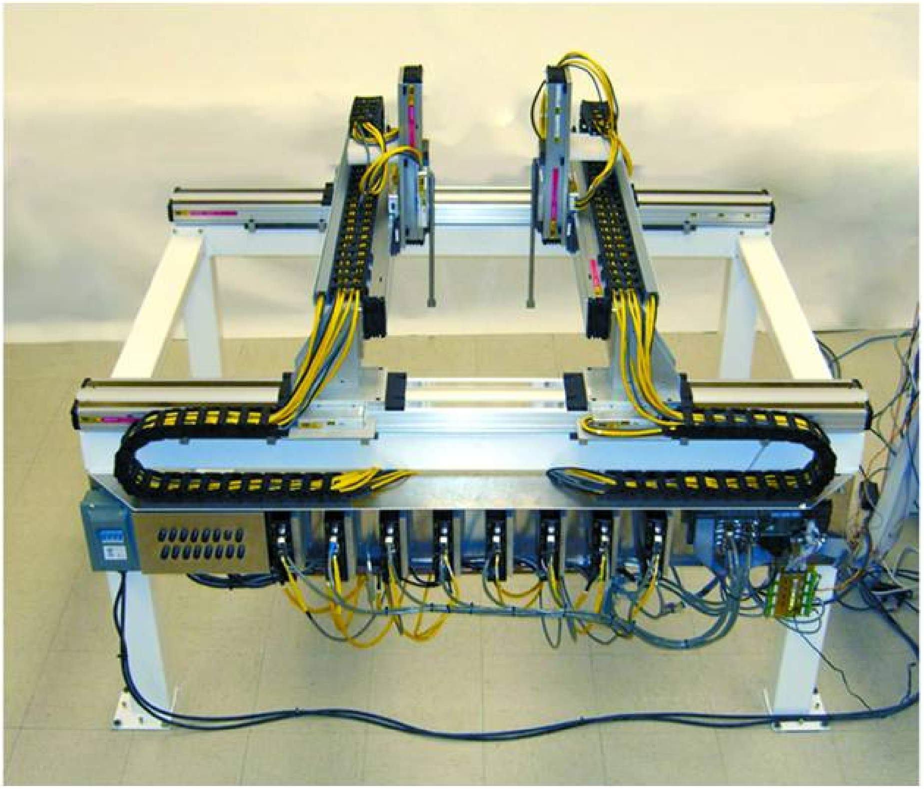

FIG. 1: The six-axes 3D positioning system (-/+ X is left/right, -/+ Y is towards/away, -/+ Z is up/down)

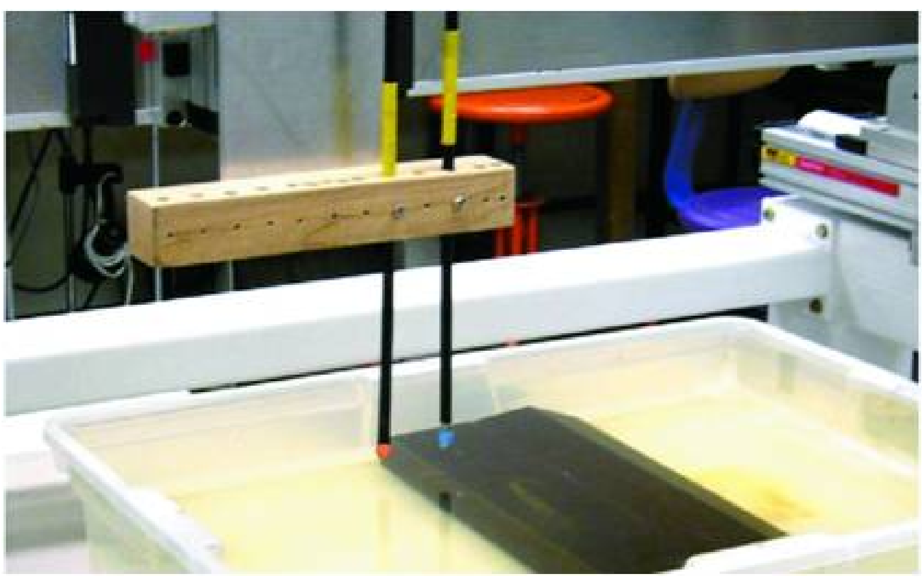

FIG. 2: A pair of hemispheric transducers simulating a source and receiver array.

Parameters	*Values field scale*
Receiver Interval	10m
Source Interval	10m
Sample Time	1ms
Number of shots	400
Type of Source	Pulse

Table 1: Seismic Parameters, Field Scale Dimensions

velocities and densities of the materials in the model were not scaled. When we referred to "field scale" that represent the field dimension and the laboratory scale will be called "laboratory scaled". Using a laboratory-scale geological model Physical seismic modelling generates a seismic response (Edwards, 1992).

In the physical laboratory experiment a source (piezoelectric transducer) emits seismic energy into the model and the reflected wavefield is recorded. The basic assumption supporting the physical modelling approach is that seismic waves propagates identically in both settings: scaled physical model and field scenario (Ebrom and McDonald, 1994). Physical modelling 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 modelling algorithms (Lawton et al., 1998).

We conducted a 2D common-offset seismic survey over the model shown in figure 3, 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).

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.

DATA PROCESSING

The raw data is shown in figure 4. The figure shows a common offset stack of all data recorded. The processing flow implemented for this data set is listed in Table 2. The dominant frequency is 35Hz. The data in general is high quality, not noisy and the reflections are well defined in the entire section. Figure 5 shows the seismic data set after processing. This data set is the input of the algorithm.

Standard Flow
Deconvolution
Velocity Analysis
Statics (No surface consistent)
Noise Attenuation filter

Table 2: Processing work flow

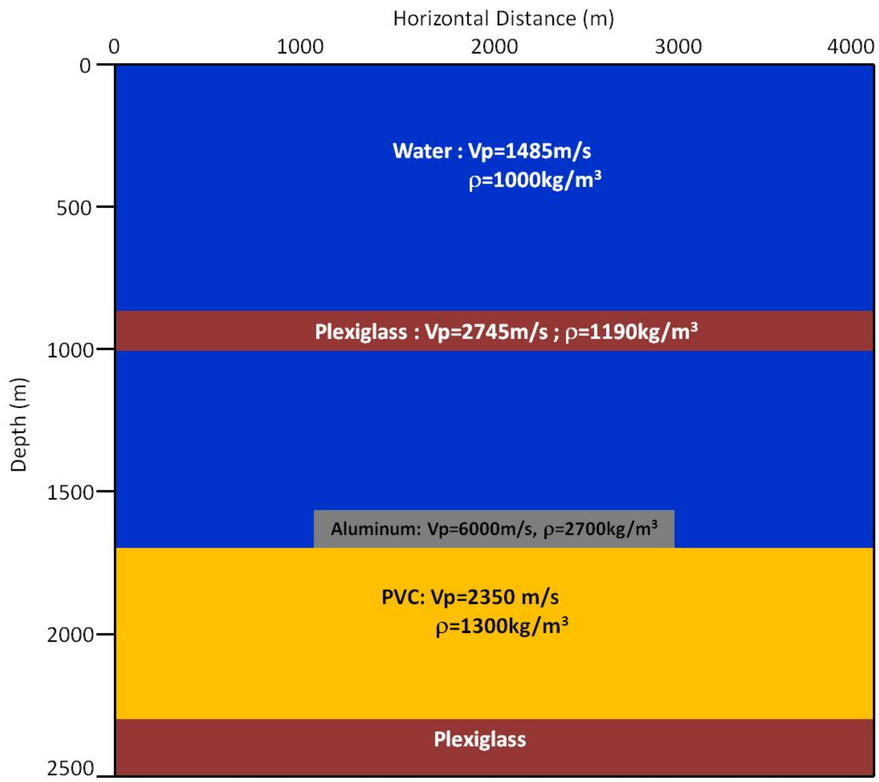

FIG. 3: Schematic diagram of the model used

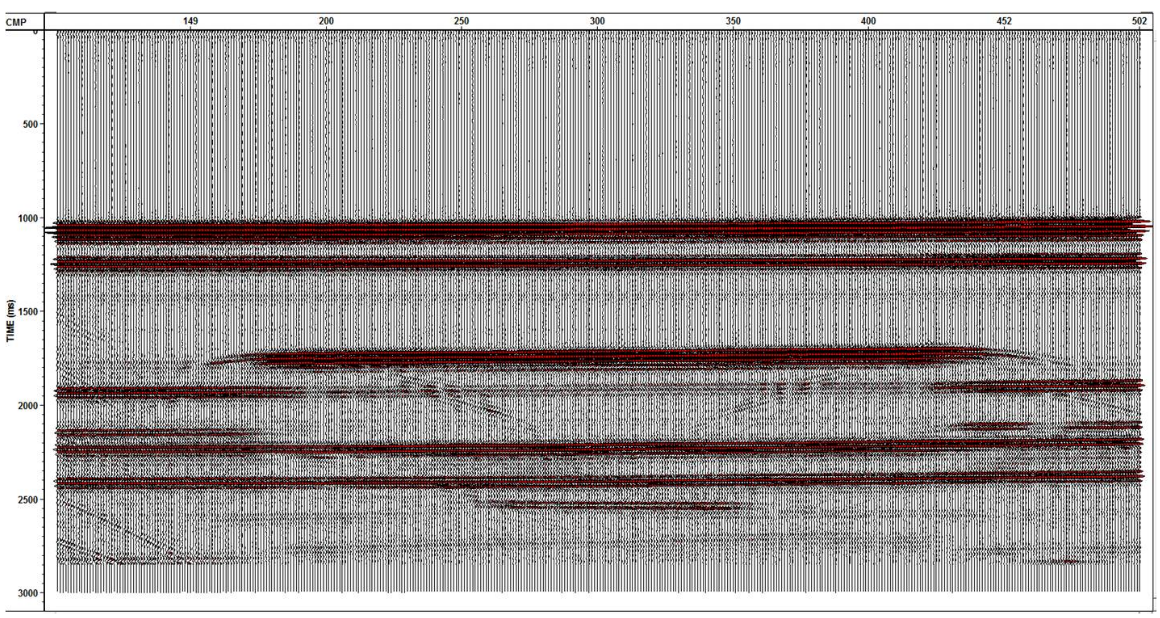

FIG. 4: Common-offset gather: raw data

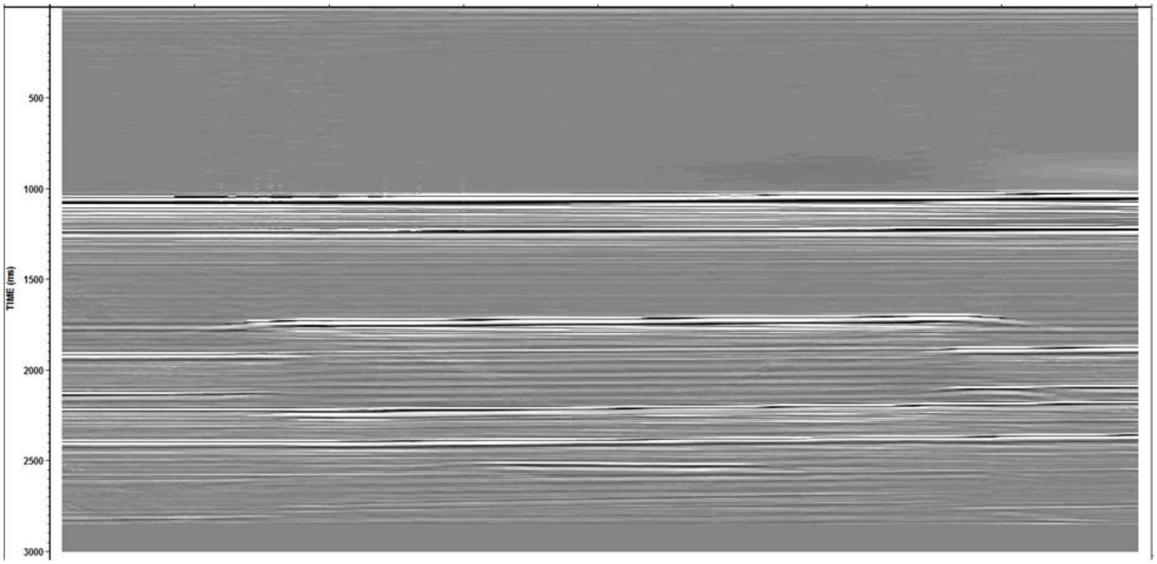

FIG. 5: Common-offset gather after processing

RESULTS

We implemented our 1D multiple attenuation algorithm on physical model data and the results are quite satisfactory. The prediction is show in figure 6. Setting at ϵ value of 50 (sample points) we predicted internal multiples reflections at 1.4,1.8, 2.1, 2.6 and 2.7 seconds as we expected according to the model.

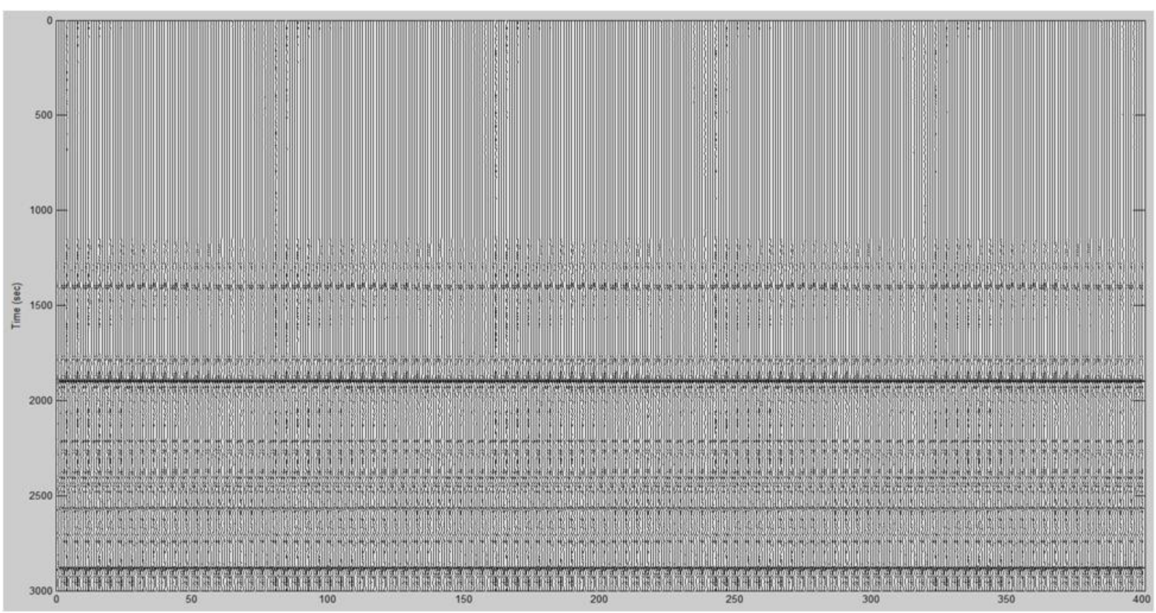

FIG. 6: Output prediction

CONCLUSIONS

In this work we implemented an inverse scattering internal multiple attenuation algorithm in phyisical model data. We conduted 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 results found indicate that for the physical model data the algorithm works satisfactory. The algorithm predicted multiples at the correct time and similar amplitudes without any a priori information about the subsurface . The output prediction depends strongly on the parameter ϵ. The value of ϵ that performed the best prediction was 50.

For future work we are planing to improve deconvolution of the physical model data prior to the implementation of the algorithm. Also we will implement the algorithm in field data.

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REFERENCES

Aki, K., and Richards, P. G., 1980, Quantitative seismology: Theory and methods.

Araujo, F. V., Weglein, A. B., Calvalho, P., and Stolt, R., 1994, Inverse scattering series for multiple attenuation: an example with surface and internal multiple: 64th Annual meeting of the Society of Exploration Geophysics, Expanded Abstracts, 1039–1041.

Ebrom, D. A., and McDonald, J. A., 1994, Seismic physical modelling: Geophysics reprint seires No .15: Society of Exploration Geophysicists, 1–3.

Edwards, D. J., 1992, 3d modelling of a reef-fault block structure: CREWES Research Report, , No. 4.

Hernandez, M., and Innanen, K., 2011, Internal multiple attenuation based on inverse scattering i: theoretical review and implementation in synthetic data: Crewes Report, **23**.

Hrabi, K. D., 1994, 3-d physical seismic modelling study of a lower cretaceous channel ins southern alberta: M.Sc. Thesis , Univ. of Calgary.

Lawton, D. C., Margrave, G. F., and Gallant, E. V., 1998, Physical modelling of anisotropic thrust: CREWES Research Report.

Mahmoundian, F., Margrave, G., Daley, P. F., Wong, J., and Gallant, E., 2011, Determinig elastic constants of an orthorhombic material by physical seismic modeling: CREWES Research Report.

Matson, K. H., Pascal, D., and Weglein, A. B., 1999, A comparison of three multiple attenuation methods applied to a hard water-bottom data set: The Leading Egde, , No. 18, 120–126.

Wong, J., Hall, K. W., Gallant, E. V., Maier, R., Bertram, M. B., and Lawton, D. C., 2009, Seismic physical modelling at the university of calgary: CSEG RECORDER, , No. 3, 36–43.