Application of amplitude thresholding to aid minimum energy adaptive subtraction for multiple attenuation

Paul Wellington, Bruce Hartley and Anton Kepic, Curtin Reservoir Geophysics Consortium*

Summary

Model based multiple prediction approaches require an adaptive subtraction step that is able to correct for differences between the real and predicted multiples. The commonly used subtraction process derives shaping operators, in the least squares sense, to minimize the energy difference between the predicted multiples and the field record. Although the minimum energy assumption allows a computationally efficient adaptive subtraction, it can lead to attenuation of primary information. This abstract illustrates how a simple amplitude clipping approach can significantly improve the effectiveness of the least squares adaptive subtraction and minimize primary attenuation.

Introduction

Multiple attenuation is regarded as one of the most important processes in modern seismic processing workflows. In regions of highly complex geology, techniques which attempt to attenuate the multiples by separability (i.e. translating to a different domain in the case of Radon Demultiple) are often insufficient (Weglein, 1999). In such cases model-based techniques which predict the multiples by using the field data are more effective. One of the best known of these prediction approaches is Surface Related Multiple Attenuation (SRMA) (Weglein et al., 1997; Berkhout and Verschuur, 1997).

Application of model-based multiple attenuation should be viewed as a process requiring two individual and equally important steps; multiple prediction and adaptive subtraction (Spitz, 1999). The first step uses a process to generate an accurate approximation of the multiples to be attenuated. The adaptive subtraction process then accounts for limitations in the multiple model that often manifest as amplitude, wavelet and timing errors. The current approach to adaptive subtraction usually revolves around application of shaping operators derived in the least squares sense. Such operators will endeavor to minimize the energy difference between the predicted multiple model and the total shot record. Although this approach tends to be convergent and computationally efficient it can have problems when there is a primary event of equal or higher amplitude than the neighboring multiples. In such a case the optimal filter will be one that attenuates the primary and leaves residual multiple energy present in the section (Guitton and Verschuur, 2004).

Previous work has been done in relaxing the need for the minimum energy criterion. One such successful example used a hybrid L1/L2 norm for the filter calculation (Guitton and Verschuur, 2004). This paper presents an alternate approach. If we have knowledge of the maximum absolute amplitude of the multiples in the section, we can constrain the shot record so that any amplitude above this value is clipped. The adaptive subtraction filters are then calculated using this clipped record. Application of this approach on simple and complex synthetics has shown favorable results.

Theory

<u>The goal of adaptive subtraction</u>

The goal of multiple attenuation is to recover a record (**P**) with a decreased amount of multiple energy present. Approaches like SRMA use the field data (**X**) to generate a prediction of the surface related multiples (**Mp**). However due to limitations in the acquisition geometry and prediction algorithms, this multiple model (**Mp**) is only an estimate of the true multiples (**M**). The relationship shared by the above components is:

$$\mathbf{X} = \mathbf{M} + \mathbf{P} \quad (1)$$

$$\mathbf{P} = \mathbf{X} - \mathbf{M} \quad (2)$$

Adaptive subtraction attempts to find a matching parameter, α filter such that:

$$\mathbf{M} \approx \alpha\mathbf{Mp} \quad (3)$$

This allows us to estimate **P**

$$\mathbf{P} \approx \mathbf{X} - \alpha\mathbf{Mp} \quad (4)$$

One of the most common approaches to accomplishing the adaptive subtraction is by generation of spatial convolution filters (*f*).

$$\mathbf{M} \approx f * \mathbf{Mp} \quad (5)$$

$$\mathbf{P} \approx \mathbf{X} - f * \mathbf{Mp} \quad (6)$$

A least squares shaping filter is, by definition the filter which will minimize the energy difference between two datasets**(**In the case of multiple attenuation these datasets are **Mp** and **X**).The construction of least squares shaping filters is described in depth by Robinson and Trietel (2000) and is not discussed further here.

<u>Application of amplitude thresholding</u>

Unfortunately the least squares technique has been shown to put too much weight on samples with the highest amplitude (Guitton and Verschuur, 2004). This lack of robustness to outliers can cause significant issues when there are high amplitude primaries in the section. In such cases the adaptive subtraction will attenuate the primary

This paper was invited by the workshop organizer and was not reviewed by the Technical Program Committee.

and often leave behind residual multiple energy. To overcome this problem, we propose extracting an estimate of the maximum absolute amplitude of the multiples in the section(Max|**M**|). Using this estimate we can then constrain the shot record so that any amplitude not within ±Max|**M**| is clipped. After applying this process the filter should be less susceptible to being controlled by high amplitude primary events, due to their amplitudes being less prominent after clipping. The filter should also be less likely to become dominated by these events as the clipping will distort the wavelet of previously high amplitude events. Figure 1 shows how clipping will alter the shape of the wavelet as its amplitude increases above the clip value.

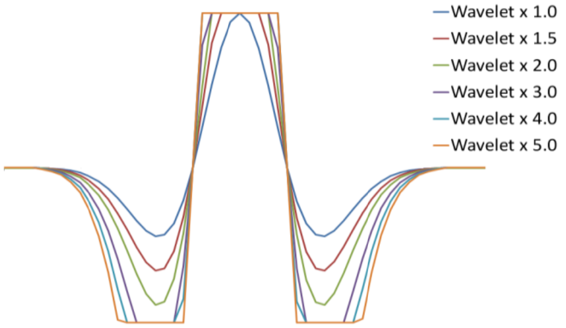

Figure 1: Effect of clipping at ±1 on a zero phase Ricker wavelet

Examples

Example 1: Two event shot record

In Figure 2 we show the results of applying the clipping on a simple 2-event synthetic. Figure 2a shows the total shot record (**X**) with a weaker multiple being overlain by a primary 5 times its amplitude. Figure 2b shows the multiple event on its own. This multiple was used as **Mp** (note in this case we have **Mp=M**). Figure 2c shows the application of the adaptive subtraction without any clipping applied. The result of the clipping approach is then shown in Figure 2d using Max|**Mp**| to clip **X** for the filter calculation. The result shows better primary preservation and less residual multiple.

Figure 3 shows how the clipped adaptive subtraction process deals with increasing primary/signal amplitude. Figure 3a-c show the clipped adaptive subtraction result for primaries/multiple amplitude of 1, 3 and 5. As the primary amplitude increases the clipped adaptive subtraction result appears more like the untouched primary (Figure 3d).

Example 2: Complex Synthetic

An acoustic model was generated with a reflecting (Figure 4a) and absorbing (Figure 4b) water-air interface. By subtracting the absorbing surface data from the reflecting we were able to generate a perfect prediction multiple model. Max|**Mp**| was used to clip the total shot record, **X**

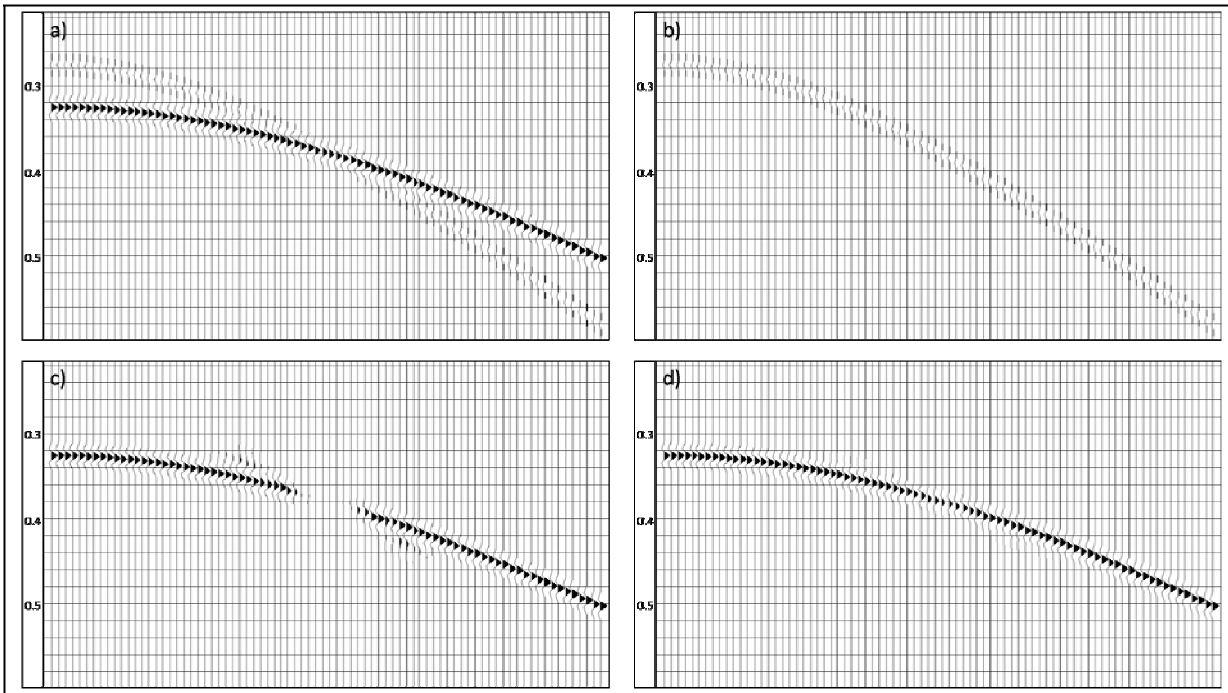

Figure 2: Adaptive subtraction of a multiple overlain by a primary with amplitude 5 times greater than it's own. a) total shot b) multiple model (Perfect Prediction) c) least squares adaptive subtraction without clipping d) least squares adaptive subtraction with clipping

This paper was invited by the workshop organizer and was not reviewed by the Technical Program Committee.

(Figure 4a) and least squares filter calculation was applied to this clipped dataset. The clipped result (Figure 4d) showed less deterioration of the high amplitude primary and a reduction in the artifacts left in the section compared to the adaptive subtraction performed without clipping(Figure 4c).

Discussion/Conclusions

The potential problems of the least squares technique is best shown by Figure 4c. The high amplitude primary at 0.9s controls the derived filter and the adaptive subtraction attenuates primary information and ends up adding in multiple energy(as seen at~1.4s). The clipping proves to be a robust approach to avoid such problems.

The results from the two synthetic examples shown are promising. The advantages of applying the amplitude clipping are two-fold. Firstly the application of clipping will decrease the contribution a high amplitude event will have to the energy of the total record. Secondly the clipping distorts the wavelet of high amplitude events. This makes these events less of a target and allow it more effectively focus on the multiples. The two event case (Figure 3) suggests that this wavelet distortion effect increases with degree to which the wavelet is clipped. The example showed improved multiple attenuation and less primary distortion for increasing primary energy (relative to the multiple).

Although this work has been applied using least squares filtering there is nothing to suggest it couldn't be advantageous to other adaptive subtraction approaches. Improvements in the performance of the adaptive subtraction after clipping can be noticed when the amplitude of the multiple is the same as the primary. This suggests the approach could be advantageous for even extremely crude estimates of the maximum multiple amplitude. However the effectiveness of the clipping approach should increase with the validity of the amplitude estimate.

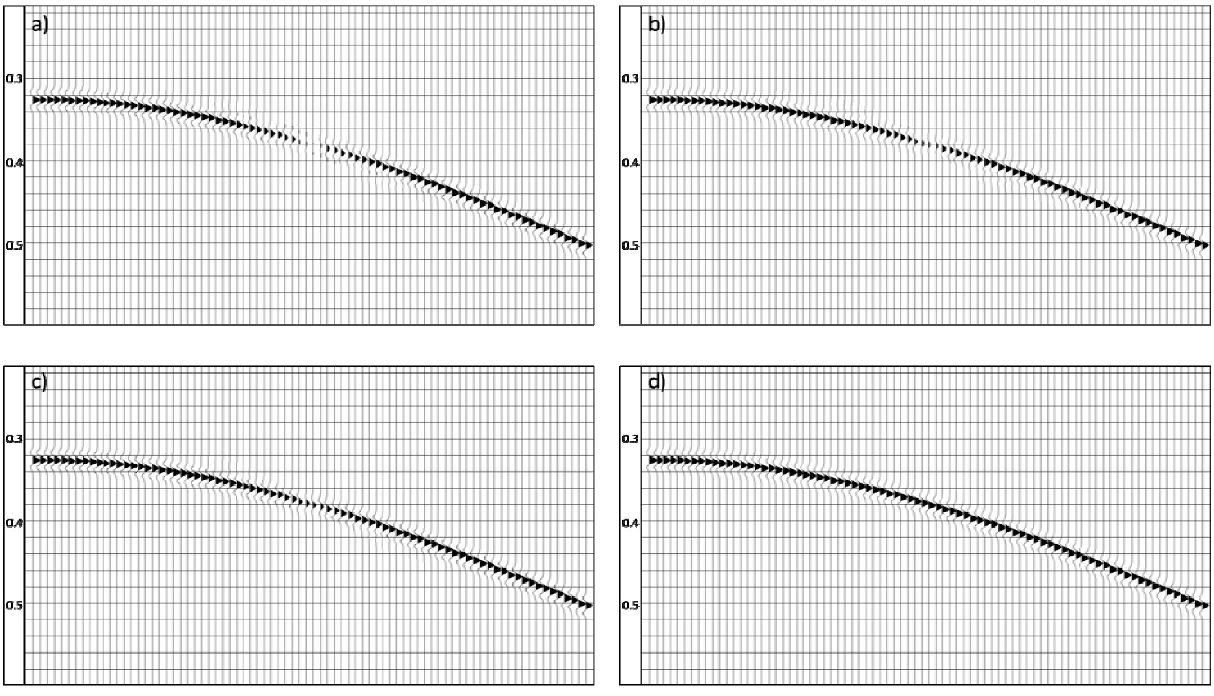

Figure 3: Effect of increasing primary/multiple energy on clipped least squares adaptive subtraction (Note records have been scaled to have the same amplitude). a) Clipped adaptive subtraction when primary:multiple amplitude = 1 b) Clipped adaptive subtraction when primary:multiple amplitude = 3 c) Clipped adaptive subtraction when primary:multiple amplitude = 5 d) Primary event (Desired result)

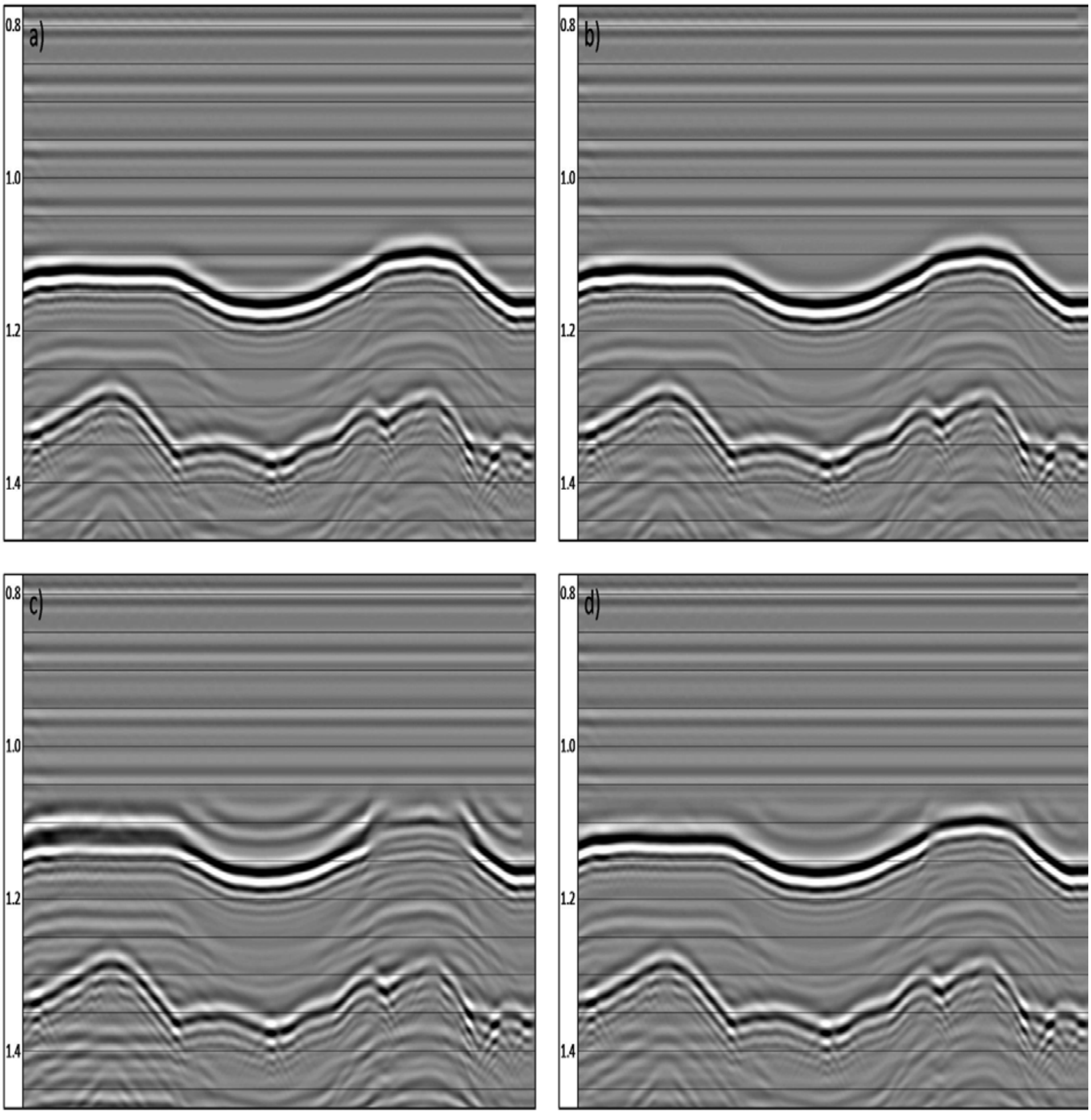

Figure 4: Example of Post-Stack adaptive subtraction on a synthetic dataset. a) Stack with free surface multiples b) Stack containing no free surface multiples c) Stack after application of least squares adaptive subtraction (no amplitude clipping) d) Stack after application of least squares adaptive subtraction (amplitude clipping applied)

This paper was invited by the workshop organizer and was not reviewed by the Technical Program Committee.