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Enhancing seismic reflection signal

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Abstract : Deconvolution is one of the most used techniques for processing seismic reflection data. It is applied to improve temporal resolution by wavelet shaping and removal of short period reverberations. Several deconvolution algorithms such as predicted, spike, minimum entropy deconvolution and so on has been proposed to obtain such above purposes. Among of them, l_1 norm proposed by Taylor et al., (1979) and used to compared to minimum entropy deconvolution by Sacchi et al., (1994) has given some advantages on time computing and high efficiency. Theoritically, the deconvolution can be considered as inversion technique to invert the single seismic trace to the reflectivity, but it has not been successfully adopted due to noisy signals of the real data set and unknown source wavelet. After stacking, the seismic traces are moved to zero offset, thus each seismic traces now can be a single trace that is created by convolving the seismic source wavelet and reflectivity. In this paper, the fundamental of l_1 norm deconvolution method will be introduced. The method will be tested by synthetic data and applied to improve the stacked section of gas hydrate.

1. Introduction

Digital signal processing is a growing and dynamic field. The seismic exploration has utilized the techniques of digital signal processing from its beginning and the geophysical advandces in this area has been catalysts for may developments in other disciplines known as deconvolution. So the purpose of deconvolution is to compress the basic wavelet in the recorded seismogram, to attenuate the reverberations and short period multiples, thus increases temporal resolutions and yields a representation of subsurface reflectivity. The process normally applied before stack; however the process is common to apply deconvolution to the stacked data (Yilmaz, 2001). There are many approaches to the deconvolution of seismic traces. Each approach has its merits. For any process of deconvolution, the seismic model must be taken into account both known and unknown factors. Based on the solutions of unknown factors, many methods of deconvolution has been proposed and given advantages and disadvantages including: Least square deconvolution, maximum likelihood deconvolution, homomorphic deconvolution, maximum entropy deconvolution, minimum entropy deconvolution, iterative deconvolution, surface consistant deconvolution and various deconvolution methods based on other criteria (Robinson and Osman,

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1996).

Given a wavelet **w** and a noisy trace $t = s * w + n$, and approximation $\hat{s}$ of reflectivity **s** can be obtained using l_1 norm. This extraction has the advantage of preserving isolated spike in s. The l_1 norm can also be used to extract the wavelet $\hat{w}$ from the trace t if the reflectivity s is known. Given a trace t and initial approximation for either s or w, it is possible to alternatively extract the reflectivity and source wavelets to improve the representation of trace t. Since the l_1 norm deconvolution can work effectively thus, it will be applied for the stacked image to remove the multiples of each seismic trace for better interpretation and analysis.

2. Review on l_1 norm deconvolution algorithm

The normal incident seismogram model can be expressed as the convolution model between three basic components: the reflectivity, s, the source wavelet w and noise, n. If we denote the free seismic trace by t then:

$$t = s * w + n \quad (1)$$

Where $*$ is denoted as discrete convolution. Assuming the source wavelet w is known, the Eq. 1 can be written in the matrix notation as

$$Ws + e = t \quad (2)$$

Where matrix W is formed from the source wavelet w by setting $W_{ij} = w_{i-j+1}$ if $1 \le i - j + 1 \le K$ and $W_{ij} = 0$ otherwise. The l_1 norm method to find the reflectivity s which will minimize:

$$\sum |e_j| + \lambda \sum |s_j| \quad (3)$$

Where parameter λ is related to the amount of pre-whitening. The spike preservation property of the noise alleviation term is one of the most important properties of l_1 norm deconvolution. Comparing to the l_2 norm the l_1 norm does not destroy the spike (Taylor et al.,1979).

In practice, it has been found advantageous to use a weighted form of Eq. 3

$$\sum p_j |e_j| + \lambda \sum q_j |s_j| \quad (4)$$

The weighted factor p_j includes the effects of any taper desired for a window and the local average magnitude of the trace. This allow the method to work effectively on ungained seismic traces. In particular, if p_j is the taper and $2H+1$ is the average window length, then

$$p_j^{-1} = \frac{1}{p_j(2H+1)} \sum_{i-H}^{i+H} t_h$$

and $$q_j = \frac{1}{100} \sum_{i=1}^{M} p_j |W_{ij}| \quad (5)$$

Which normalizes λ between 0 and 100. The problem as formalized in Eq. 4 can be solve by using any l_1 norm solution which is described in detail by Taylor et al., 1979.

3. Application of deconvolution to the gas hydrate dataset

The result algorithm of l_1 norm is shown in Fig. 1 where Fig.1a shown the true reflectivity, Fig.1b show the seismic trace convolving from the Ricker source wavelet (with central frequency f=20Hz) and seismic reflectivity. The Gaussian random noise was added to the seismic trace. Fig.1c and Fig.1d present the inverted reflectivity and predicted seismic trace, respectively. Comparing Fig.1a and Fig. 1c we may see the result of l_1 norm give quite good in term of position and amplitude and Fig. 1d indicate the improve the original seismic trace. One more general example of l_1 norm deconvolution is shown in Fig. 2 when the actual seismic reflectivity was generated randomly base on Gaussian distribution. Similarly the source wavelet was used in this case is Ricker source wavelet (with central frequency f=20Hz). Hence, we may see the improvement of seismic trace by comparing Fig. 2b and Fig. 2d.

The data set was acquired by KIGAM seismic acquisition team in 2003 for the gas hydrate exploration. The receiver interval was 12.5m and shot interval was 25m. Each shot gather consists of 80 channels or traces. The preprocessing steps included: muting, band-pass filter, deconvolution and automatic gain control for each source gathers. Fig. 3a and 3b show the shot gather #3700 and its preprocessing result, respectively.

After CDP sorting, velocity analysis and NMO correction, the stack section will be made as shown in

Fig. 4. After stacking, the seismic trace now can be considered as single vertical downward continuation that is similar to the convolution of seismic source and reflectivity. Thus, it can be applied l_1 norm deconvolution to get better stack image. The result of l_1 norm deconvolution is shown in Fig. 5 and Fig. 6 in which Fig. 5 present the reflectivity profile and Fig. 6 present the improved stacked section.

4. Conclusions remarks

The l_1 norm deconvolution can be used to generate qualitatively the seismic reflection and enhance the stacked image. The result obtained from deconvolution for seismic section of field data set as presented above use the Ricker source wavelet, the other source wavelet should be studied and applied widely for real data set in oder to get the best results of seismic section.

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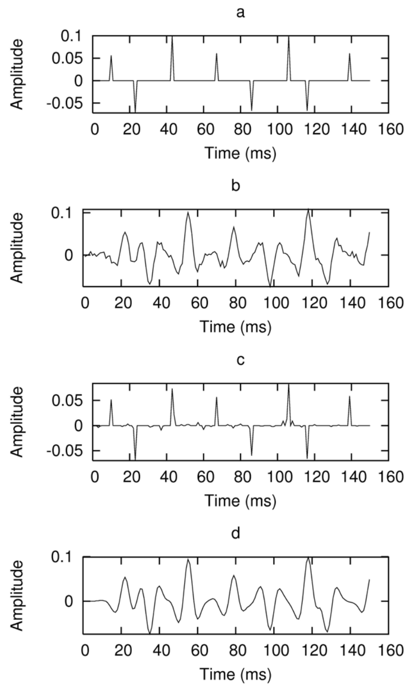

Fig. 1. l_1 norm deconvolution result with given reflectivity model.

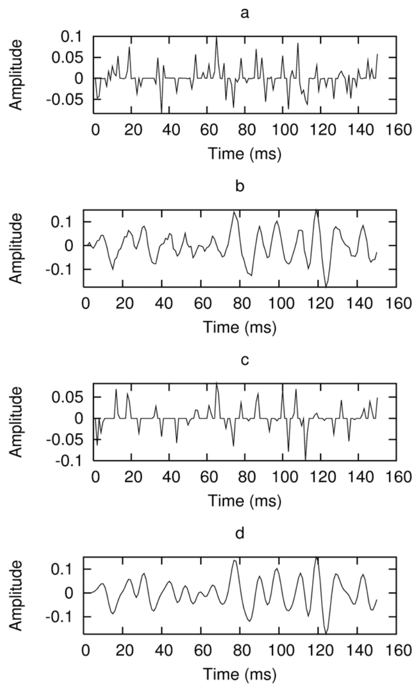

Fig. 2. l_1 norm deconvolution result with randomly generated reflectivity model.

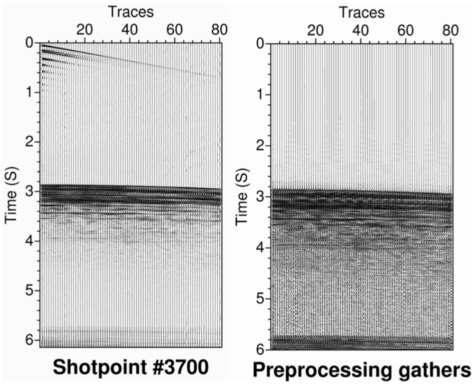

Fig. 3. Shot gather #3700 and its preprocessing results.

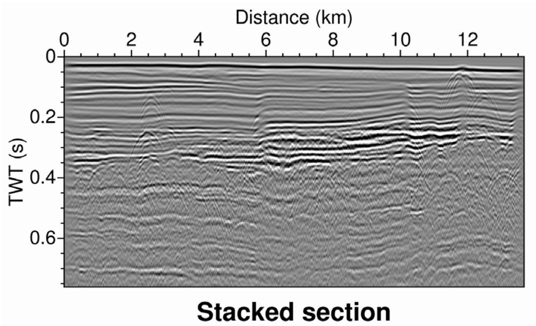

Fig. 4. Stacked imaging of seismic data.

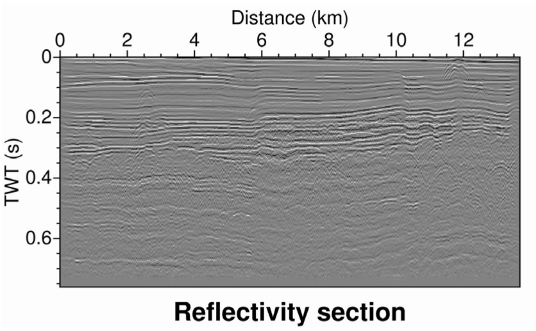

Fig. 5. Inverted seismic reflectivity based on l_1 norm.

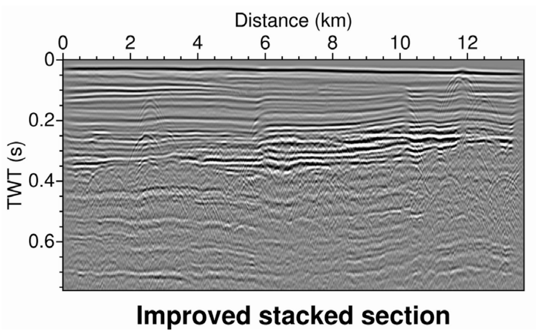

Fig. 6. Improved stacked section base on l_1 norm.