A Semblance Weighted Radon Transform on Multiple Attenuation

Zhihong Cao and John C. Bancroft, University of Calgary, Calgary, Canada

2005 CSEG National Convention

Introduction

The Radon transform is defined by Johan Radon (1917) as an integral of some physical property of a medium along a particular path, which is given by

$$u(\tau,q)=\int_{-\infty}^{\infty} d(h,t=\tau+q\varphi(h))dh\,. \tag{1}$$

In exploration geophysics d(h, t) is the original seismogram, u(τ, q) is the modeling data in the Radon transform domain, t is the two way time, h is a spatial variable such as offset, τ is the intercept two way time, q is the slope of the curvature based on which the transform trajectory is defined, and φ(h) defines the curvature.

The conventional inverse Radon transform is given by

$$d'(h,t)=\int_{-\infty}^{\infty} u(\tau=t-q\varphi(h),q)dq\,. \tag{2}$$

In recent years, the Radon transform approaches have attracted attention on multiple attenuation. However, the Radon transform has its weakness. Because of energy sharing at near offsets on CMP gathers, a smearing problem occurs seriously in the Radon domain, which decreases its resolution.

In order to minimize this smearing problem, investigators have tried different solutions for almost twenty years. Thorson and Claerbout (1985) worked on a least-squares method and a stochastic inverse method. The latter one has a relative high resolution but it is very expensive. To quicken the computation speed, Hampson (1986) moved the problem into the frequency domain and used a parabolic Radon transform. Yilmaz (1989) also worked on the parabolic Radon transform by t^2-stretching the time axis of seismology. Beylkin (1987) applied a *rho* filter prior to integration over the q parameter in the inverse Radon transform. Zhou and Greenhalgh (1994b) showed that applying the *rho* filter in the forward Radon transform rather than the inverse transform could give better resolution in the modeling space. Sacchi and Tadeusz (1995) proposed an improved algorithm for the parabolic Radon transform by using the previous transform results as a priori information. Ng and Bradshaw (1987) and Ng (2004) introduced a time domain semblance weighted Gauss-Seidel forward Radon transform.

Semblance Weighted Radon Transform

The semblance weighted hyperbolic Radon transform is given by Ng and Bradshaw (1987):

$$u(\tau,q)=S(\tau,q)\sum_{h} d\left(t^2=\tau^2+q*h^2,h\right). \tag{3}$$

Here S(τ, q) is the semblance of the input seismic data given by

$$S(\tau,p)=\frac{\sum_{l}\left(\sum_{h} d\left(t^2=\tau^2+ph^2,h\right)\right)^2}{N_h\sum_{l}\sum_{h} d^2\left(t^2=\tau^2+ph^2,h\right)}. \tag{4}$$

where N_h is the number of traces involved in the semblance, and l is a window size, usually a wavelet length.

Weighting the Radon transform by semblance gives better resolution than the conventional Radon transform, but an even much more improved method can be obtained if semblance is taken as a priori information prior to performing the forward Radon transform. Perform forward semblance weighted Radon transform in order of the descending power of q trace to get u(τ, q), i.e. first perform the Radon transform on the best fit trajectory of events, remove the amplitudes along this trajectory from the original input data, then move to the second best fit trajectory of events, and so on.

Application

This method is designed for the purpose of multiple attenuation. The synthetic input data of the example is shown in Figure 1 and the modeling data in the Radon domain is shown in Figure 2. Primaries are muted in the Radon domain, and multiples are reconstructed in time-space domain (Figure 3). Finally multiples can be attenuated from the original input data by a nonlinear filter (Zhou, and Greenhalgh, 1994a) (Figure 4).

It can also be a good tool to do velocity analysis. Figure 6 and Figure 7 are the semblance plot and the Radon plot of the input seismic data in Figure 5 respectively. Comparing Figure 6 and Figure 7, the Radon transform gives much better resolution than the semblance plot. On the semblance plot, it is hard to follow where to go to pick velocities.

Discussion

The semblance weighted Radon transform, taking the semblance as a priori information, is working on the time-space domain. It is not necessary to approximate the seismic events as parabola. Working on the hyperbolic Radon transform is more accurate than the parabolic Radon transform. This method gives high resolution in the Radon domain and it is very effective on computation.

Acknowledgement

I would like to acknowledge Mark Ng for discussion on the semblance weighted Gauss-Seidel method of the Radon transform. Thanks my supervisor John C. Bancroft for his supervision and suggestions. Thanks the CREWES Project, Santos Ltd, CSEG Scholarship Trust Fund, Devon Canada Corporation, Matrix Geoservices Ltd., SEG Foundation and GRS for funding support.

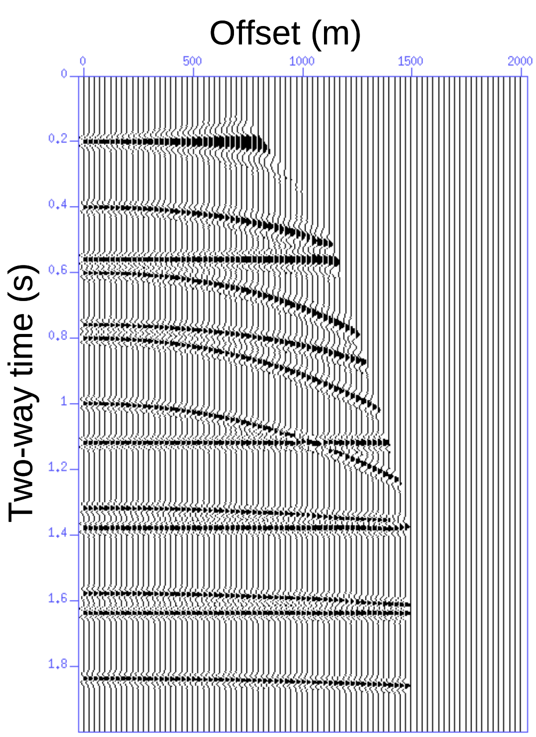

Figure 1 An NMO-corrected muted synthetic CMP data.

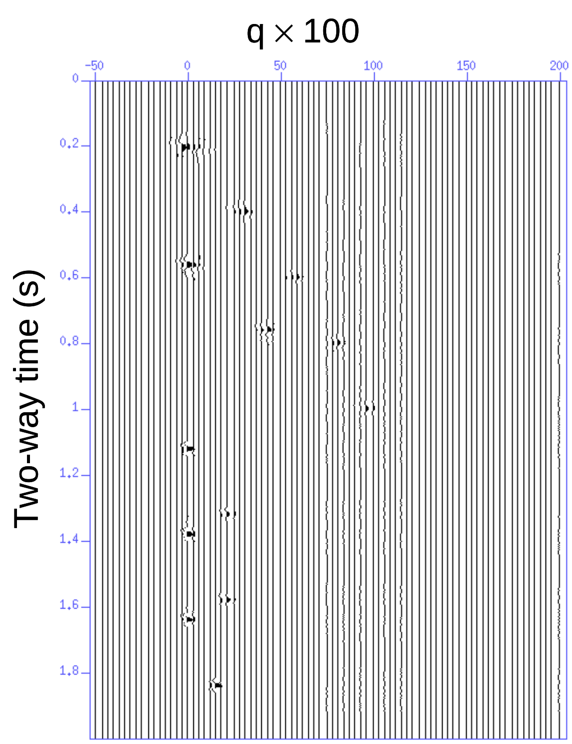

Figure 2 The Radon domain data of Figure 1. Primaries are aligned along q=0. The rest are multiples

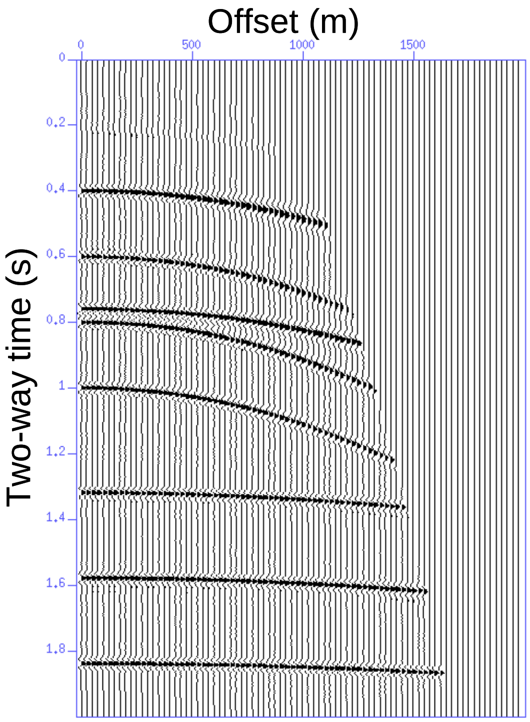

Figure 3 The reconstructed multiples in time-space domain.

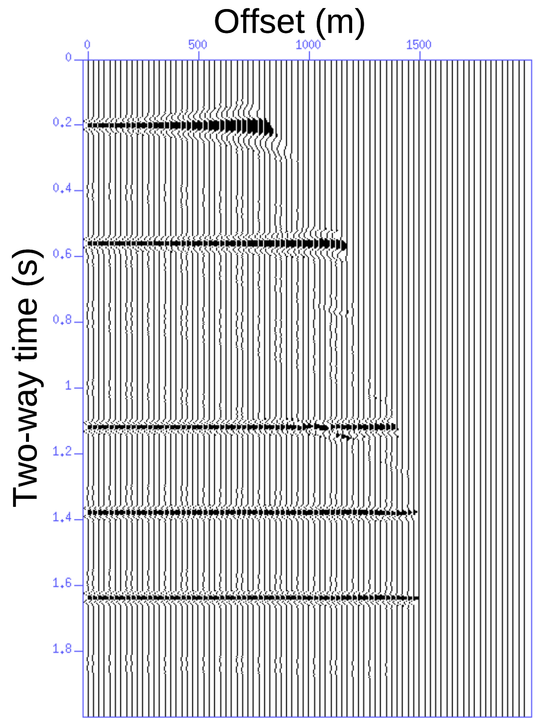

Figure 4 The primaries after nonlinear filtering of multiples in time-space

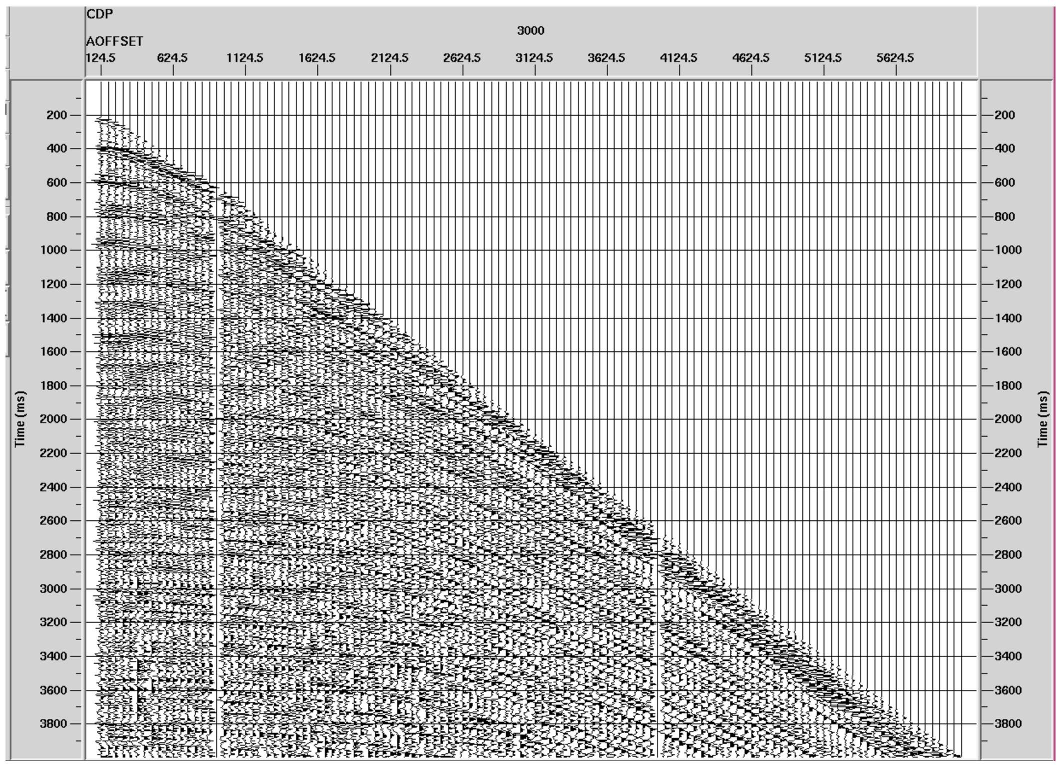

Figure 5 The input seismic CMP gather

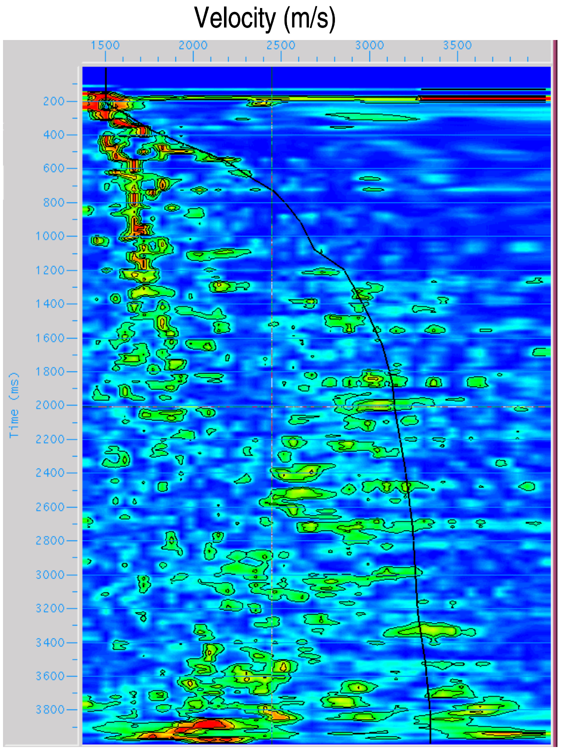

Figure 6 The semblance of the input CMP gather in Figure 5

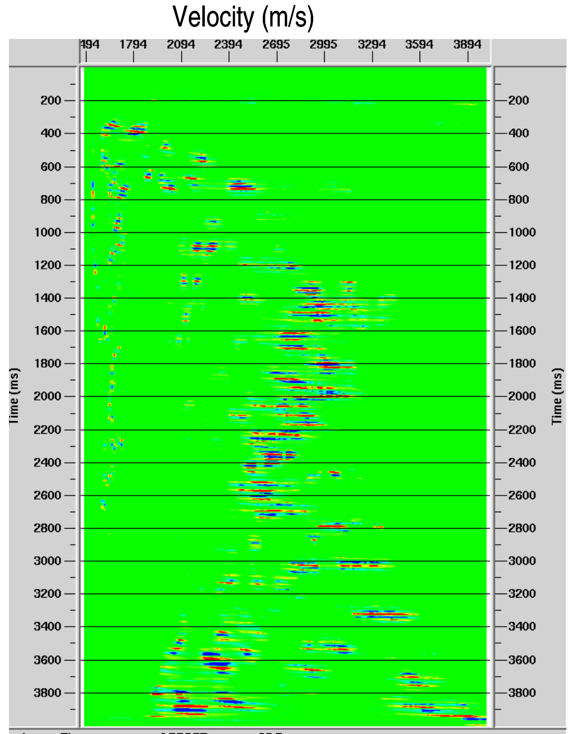

Figure 7 The Radon domain data of the input CMP gather in Figure 5

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