Application of GPU on Seismic Data Processing

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Abstract

GPU has been performed in Prestack Time Migration (PSTM) and Reverse Time Migration (RTM) for years, now further applied on conventional data processing. Using Short Time Fourier Transform (STFT), the input data to be solved in terms of not only in time-space or frequency domain, but also in both space-time and frequency domain at the same time. It can be utilized for despiking, coherence noise removal, demultiple, etc. with less side effects than traditional. However, every sample needs to do FFT, the calculation is intensive. In virtue of GPU parallel computing, the application of STFT method has excellent results.

RTM and Modeling on GPU

We use finite difference method (FD) to solve the acoustic wave equations. In order to avoid numerical dispersion and instability of the wave equations, 4th-order FD in time domain, 8th-order in x, y direction and 16th-order in z direction in spatial domain are applied.

The forward modeling shots are generated by high order FD based on the 2D model as shown in Figure 1a and performed RTM seismic imaging. The result shown in Figure 1b is matched with the velocity model completely.

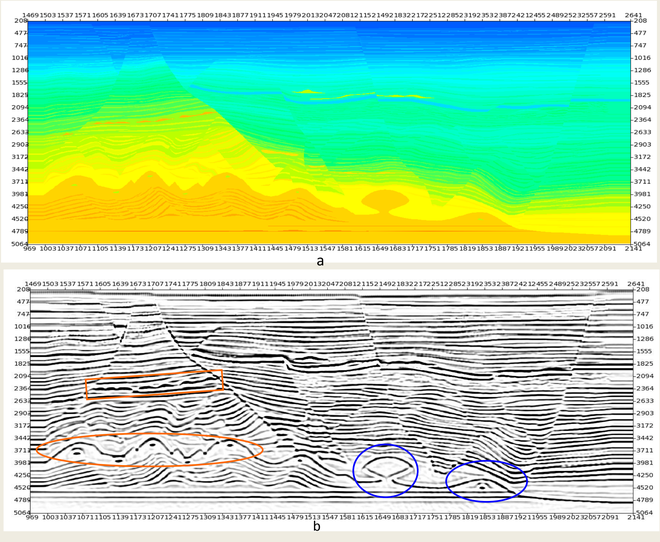

Figure1. a) 2D Model. b) RTM result.

Two sections by using Kirchhoff PSTM and RTM are depicted in Figure 2. The imaging accuracy of steep dip structure on RTM result is much higher than that on PSTM result.

RTM and Modeling on GPU

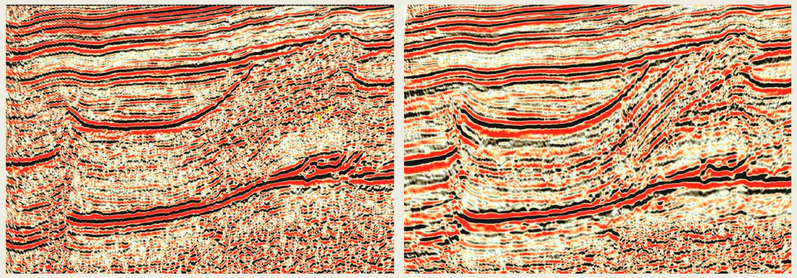

Figure 2 a) Kirchhoff PSTM section. b) RTM Section.

Seismic Denoising on GPU

STFT maps 1D time domain signals to 2D time-frequency signals. The equation is given as follows:

$$S_x(\omega,t)=\int x(\tau)W(\tau-t)e^{-j\omega\tau}d\tau$$

where W is windowing function.

STFT computes a time-frequency spectrum for each input trace that every sample on seismic trace will be transformed. If short window has N samples, after STFT, there will have [N/2+1] real samples and [N/2+1] imaginary samples. Rearrange the data according to the sequence [N/2+1], trace number and trace samples after whole shot record transformed, then will get [N/2+1] sub-band records for the real part and [N/2+1] sub-band records for the imaginary part. We choose 32 samples and rearrange the data to form separate real parts and imaginary parts (Figure 3).

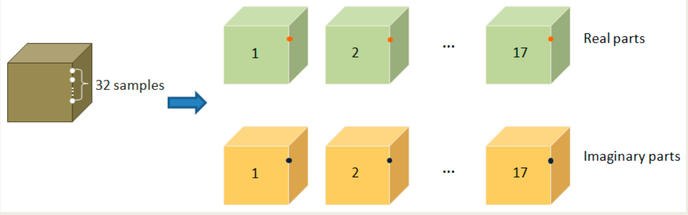

Figure 3 32 samples scheme of STFT.

Despiking

Other than abnormal trace removal directly, as much of the overdriven noise component as possible could be removed for optimal results. The spike traces still remain instead of being removed or zero setting. The result of despiking in STFT domain is displayed in Figure 4.

Seismic Denoising on GPU

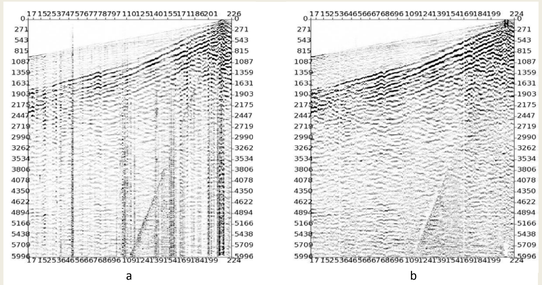

Figure 4 a) Shot with abnormal traces. b) Abnormal frequency is removed in STFT domain but useful part of frequency in the trace still remains.

Linear Noise Removal

Different speed is applied for linear moveout (LMO) correction. If the linear noise is flattened, then it will be horizontally filtered. Meanwhile, the useful reflection in the form of the hyperbola can never be flattened and survived after filtering. In Figure 5, the reflection is much more obvious after linear noise removal.

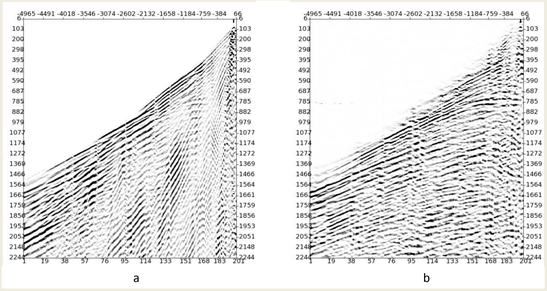

Figure 5 a) Shot before linear noise removal. b) Shot after linear noise removal.

Demultiple

Normal moveout (NMO) correction is applied on CDP gather by multiple velocity. The flattened multiple is easily filtered in horizontal direction. STFT method can help reduce the side effects with less reflection removed. The CDP gather after multiple velocity NMO is displayed in Figure 6a, Figure 6b shows the gather after horizontal filtering. It is much clearer in their velocity spectrums (Figure 6c and 6d).

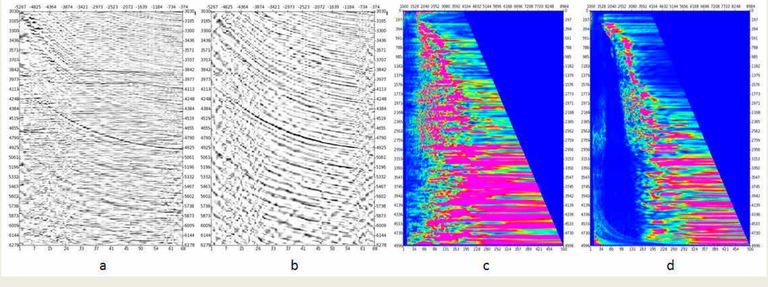

Figure 6 a) CDP gather after multiple velocity NMO. b) CDP gather after horizontal filtering. c) Velocity spectrum before demultiple. d) Velocity after demultiple.