Application of GPU on Seismic Data Processing

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Abstract

Many computation-intensive methods have already been applied on GPUs for seismic data processing such as Reverse Time Migration (RTM), Pre-stack Time Migration (PSTM), now further applied on Surface-related Multiple Elimination (SRME), data regularization, pre-stack denoise in short time FFT domain, TTI Pre-stack Depth Migration (PSDM), and TTI-PSDM velocity modeling. In virtue of GPU parallel computing, these algorithms can get realized efficiently and have excellent results.

Marine Data Regularization

Marine data processing requires regularization to handle irregular recording geometries, missing shots, etc. The combination of DMO and DMO^{-1} is used to reconstruct data to a cell grid (x, y), DMO method can rotate the source-receiver line from its original azimuth to zero azimuth which is more convenient for further processing.

Forel and Gandner (1988) write DMO algorithm as:

$$k^2 = h^2 - b^2$$

$$t_1 = t \cdot \frac{k}{h}$$

where h is the half offset of input trace, k is the half offset of the replacement trace, b is the distance of the replacement trace from the source-receiver midpoint along the source-receiver line, t is the input time, and t_1 is the output time.

GPU interpolation is performed for missing trace using Short Time Fourier Transform (STFT) method to obtain a regular 3D survey. Figure 1 displays the common midpoint (CMP) gathers before and after regularization with the fold maps. The calculation is intensive since every sample needs do STFT, interpolation job on CPUs is very slow yet on GPUs can achieve a 5x speedup.

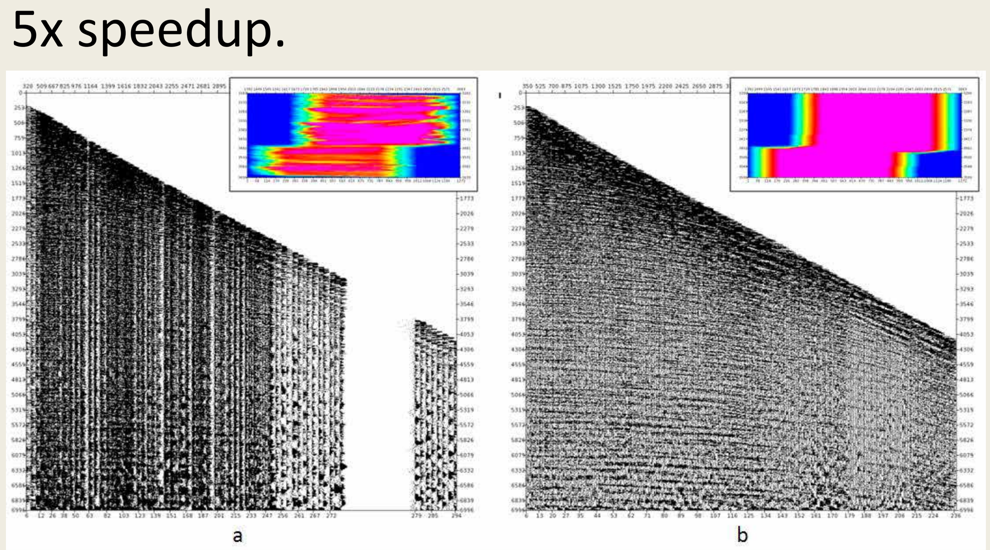


Figure 1 (a) CMP gather before regularization and its fold map, (b) CMP gather after regularization and its fold map.

3D SRME

SRME is an algorithm that predicts all surface multiples which can be adaptive subtracted from original shots. It can attenuate both near-offset multiples and far-offset multiples rather than multiple removal in the *f-k* or *τ-p* domain which cannot eliminate short-offset multiples. Surface multiples can be predicted by convolving the traces of a common-shot gather with those of a common-receiver gather. Summation of the traces can form the predicted surface multiples.

The surface-related multiple for 3D cases is presented as (Dragoset et al., 2010) :

$$M(x_r, y_r, \omega; x_s, y_s) = r_0 \sum_{x_k, y_k} R(x_r, y_r, \omega; x_k, y_k) D(x_k, y_k, \omega; x_s, y_s)$$

where $R(x_r,y_r,\omega;x_k,y_k)$ describes a common-receiver gather for a source at $(x_k,y_k,z=0)$ and a receiver at $(x_r,y_r,z=0)$, and $D(x_k,y_k,\omega;x_s,y_s)$ describes a common-source gather for a source at $(x_s,y_s,z=0)$ and a receiver at $(x_k,y_k,z=0)$ in frequency domain, r_0 represents reflection coefficient.

SRME is burdened by strict requirement on data that each cell point must have traces, this issue has been solved by data regularization, but there are still two other challenges for SRME application on GPUs:

1. How to sort data into common-source gather and common-receiver gather efficiently
2. How to do 3D SRME in a limited GPU memory

To solve the sorting problem, common-offset domain is adopted for 3D SRME. Two different common-offset data are used for the convolution calculation at the same time, the volume of all source and receiver data with two offset values can fit in the limited GPU memory and accomplish FFT on GPUs. The memory problem can be solved by using a small portion of lines, and overlap some lines on both sides to avoid boundary problem. The parallel computing can get 5x faster than on CPUs.

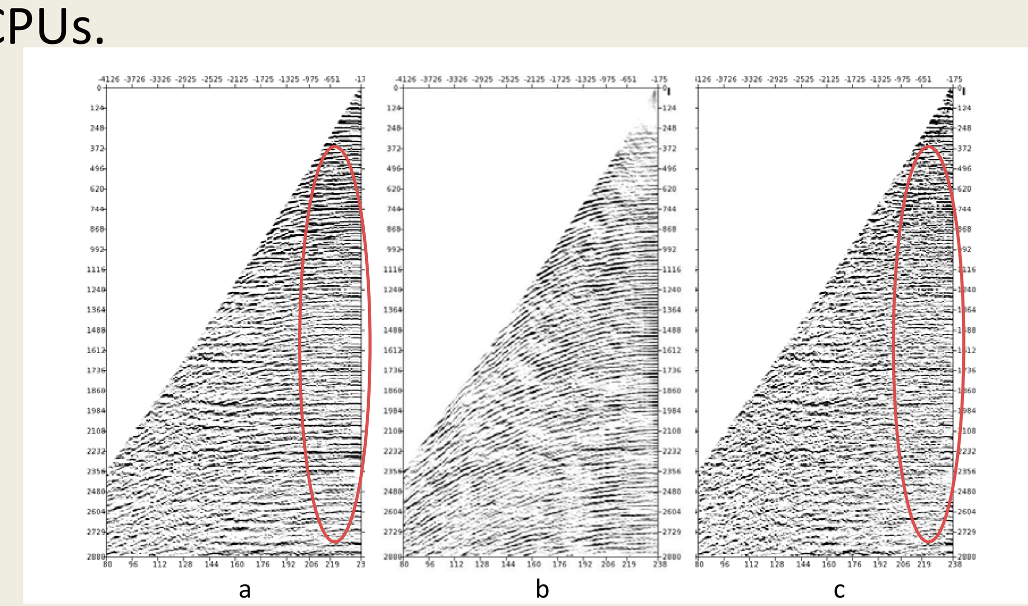


Figure 2 (a) Original NMO gather. (b) Predicted surface-related multiples gather obtained by summation. (c) SRME gather by adaptive subtraction from the original data.

3D SRME

The predicted multiples gather is displayed in Figure 2b, it can be removed from the data (Figure 2a) by adaptive subtraction to obtain SRME gather as shown in Figure 2c.

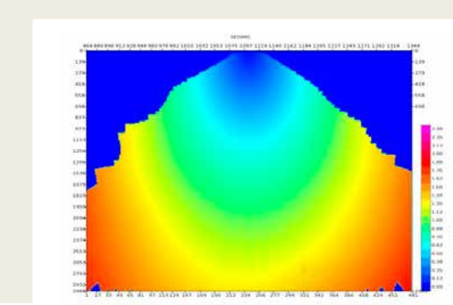
3D TTI-PSDM & Velocity Modeling

TTI-PSDM involves two main steps: creating a ray tracing table, and utilizing time table to do PSDM. For 3D time tracing table, the number of rays consists of a number of dip-x rays multiply by a number of dip-y rays, usually tens of thousands of rays. Interpolation is adopted by three adjacent rays to obtain the grid point value, the value is saved to disk to form a ray tracing table (Figure 3a). There are five parameter volumes take TTI media into account — vz, delta, epsilon, dip-x, dip-y. Calculation for each volume is intensive, using GPUs can accelerate the computation.

The other step is reading time table to do PSDM, time table is a coarse grid that traces could be at any position, it requires interpolation of the time table for both source points and receiver points using adjacent time tables. Calculation intensive 3D interpolation on GPUs can achieve 10x speedup.

Tomography method is applied for velocity model building to modify the velocity model. Picking the residual velocity first to modify parameter vz, using scan method to find best epsilon parameter, using well log data to determine delta parameter, the dip-x and dip-y parameters can be calculated on seismic section.

The TTI-PSDM results before and after velocity model modification are shown in Figure 3.



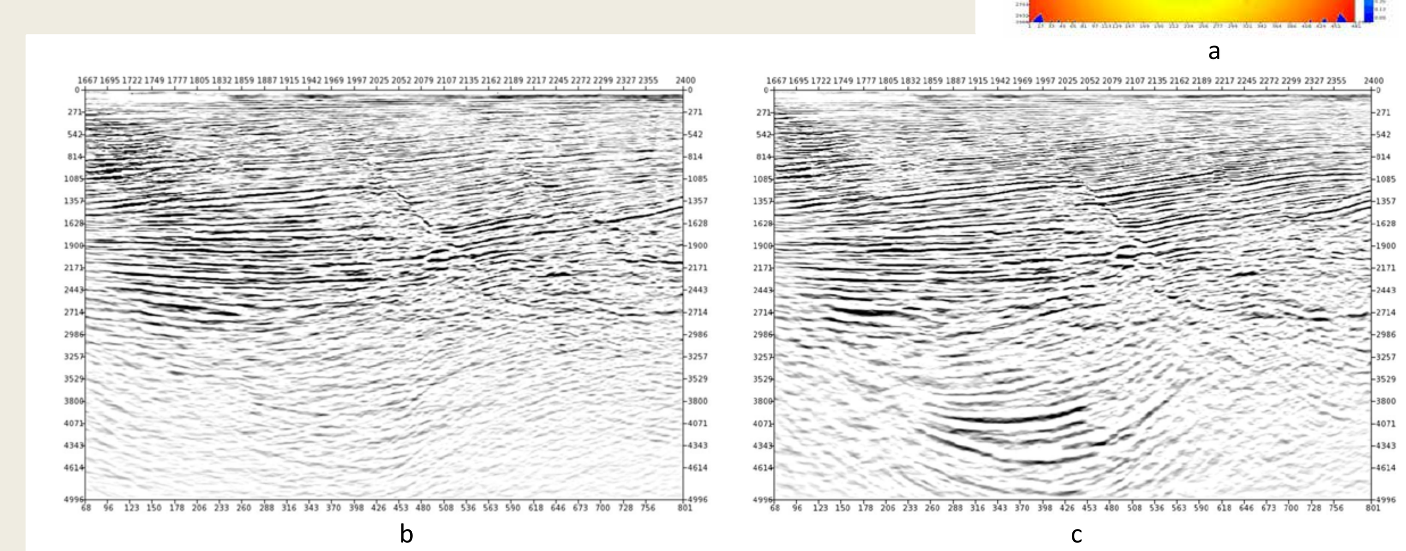


Figure 3 (a) 3D TTI ray table. (b) TTI-PSDM section before velocity model modification. (c) TTI-PSDM section after velocity model modification.