SEISMIC ATTRIBUTES COMPUTATION ON GPUs

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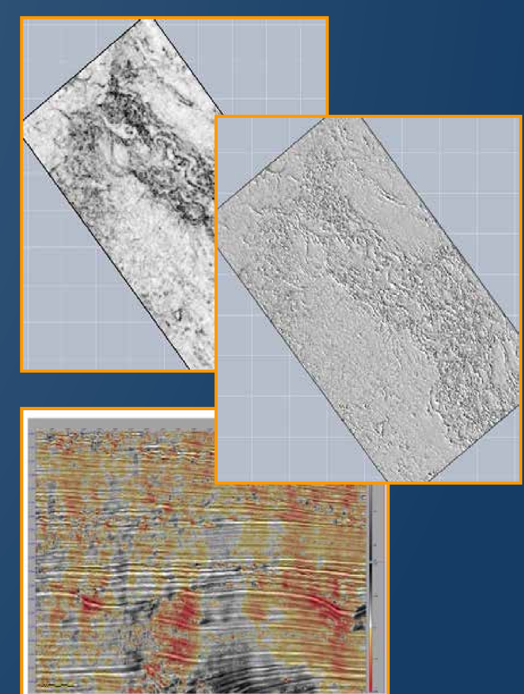
Introduction

Seismic attributes are quantities derived from seismic data to highlight features of interest.

In seismic interpretation seismic attributes are key to better understand structural and sedimentary features present in seismic images.

Use of GPUs to speedup seismic attributes computation

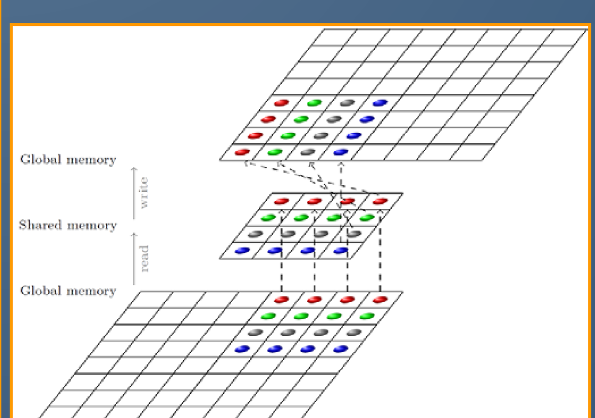
- Interpretation should ideally be interactive
- Seismic attribute computation algorithms are parallel
- Interpretation workstations are usually equipped with powerful GPUs for visualization



Several attributes have been ported to CUDA and show significant performance boost.

3D Gaussian Smoothing

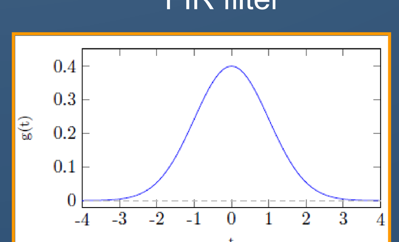
Gaussian smoothing is applied as 3 independent one-dimensional filters implemented as a unique CUDA kernel. Data is simply transposed after each step.



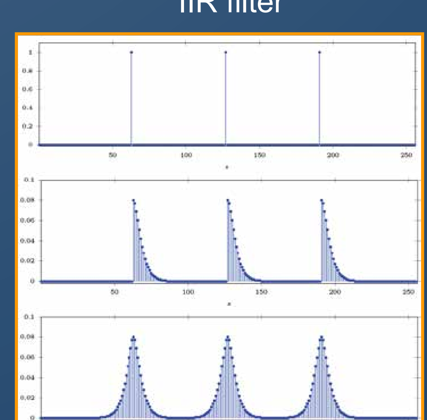
An efficient 3D transpose kernel is thus required to transform seismic datasets from the original trace oriented data layout (suited for visualization) to any convenient layout for computation.

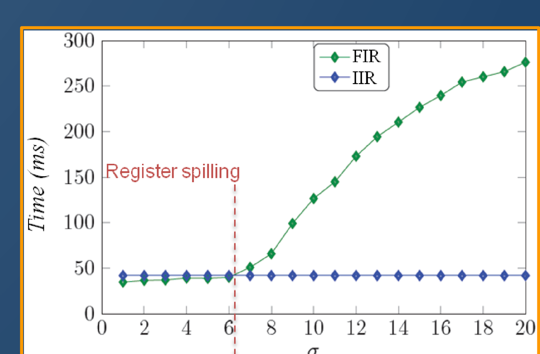
The proposed algorithm uses 3D grids and shared memory to perform the transpose operation. It achieves 80% of the memcopy memory bandwidth.

FIR filter



IIR filter



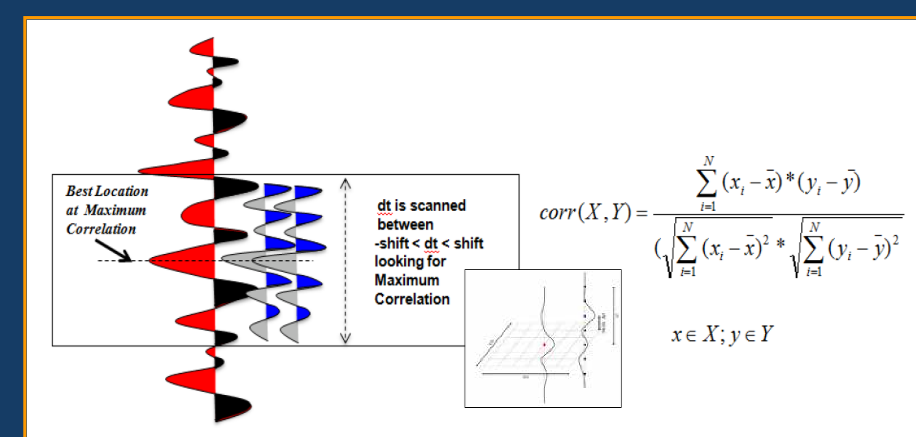


$$y[i] = \sum_{k=i-M\sigma}^{i+M\sigma} g[i-k]x[k]$$

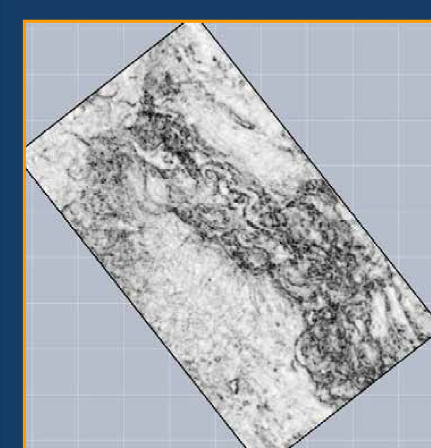
IIR vs FIR filters: FIR implementation performs better for small filters, while, due to register spilling, IIR implementation is more efficient for large filters. On Kepler GPUs, thanks to a higher number of available registers per thread, register spilling for FIR implementation is observed for σ>20 .

23X speedup over CPU IIR filter implementation

Cross-Correlation based Seismic Attributes



Coherence



The coherence measures the correlation between adjacent seismic traces and hence evaluates their difference. This attribute detects major faults, but subtle faults are usually poorly defined with this technique.

CUDA implementation uses one thread per seismic trace and is based on a register sliding window along seismic traces to reduce global memory access.

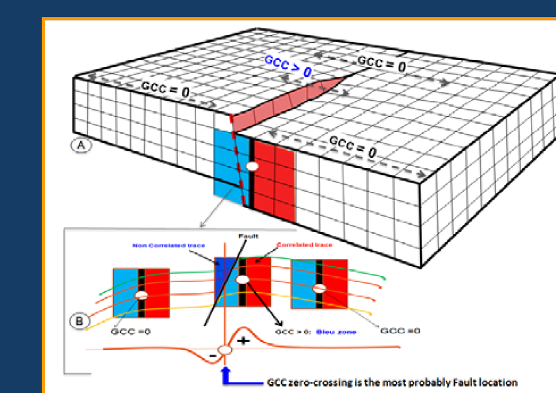
30X speedup over CPU implementation

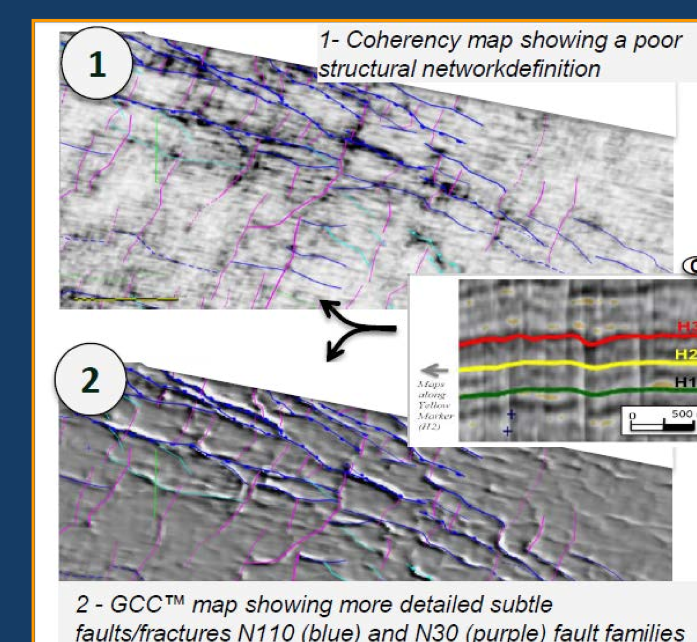
Compared to an optimized OpenACC implementation, the CUDA version of the coherence attribute shows a 3X speedup.

Gradient Correlation Cube™

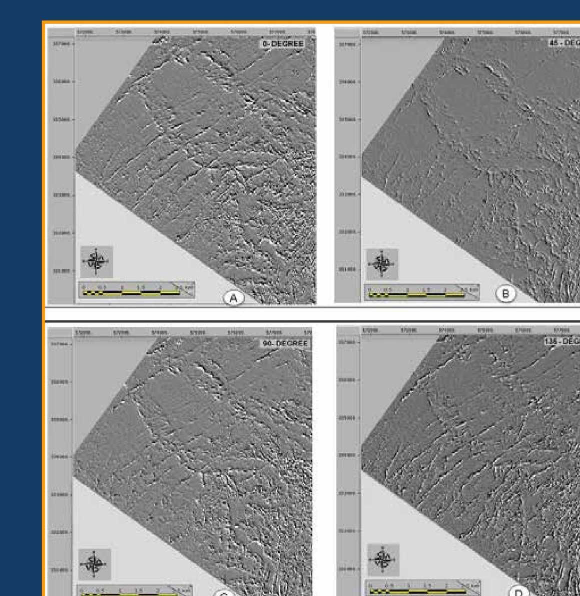
GCC™ attribute optimizes the detection of subtle faults and fractures especially in carbonate environments where seismic quality is generally poor.

GCC™ captures the local variation of the coherency. The Fault location is not longer defined by the local extrema of the coherency attribute but by the zero-crossing of the GCC™ attribute. This is more visible and accurate compared to the local extrema.





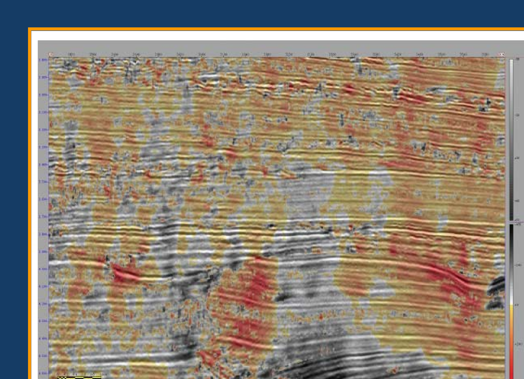
GCC™ also computes the lateral variation along different azimuths. The multi-azimuthal property is needed to adjust the GCC™ kernel to the local fault azimuth and hence maximize its detection and location.

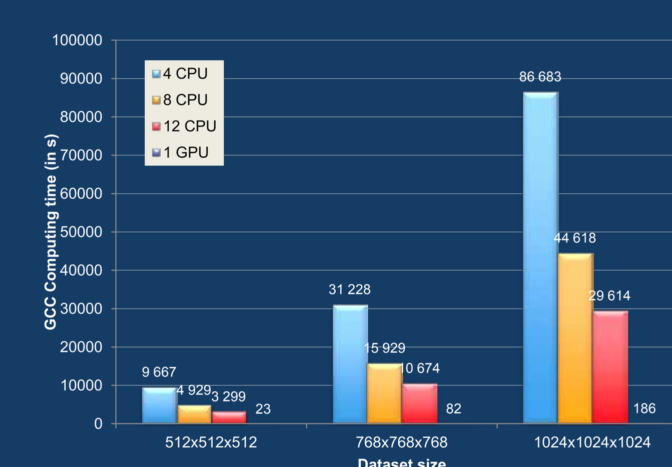


Dip/Azimuth

By performing a linear regression on the positions of maximum correlation for the neighboring traces, we can infer the orientation of the geologic features.

10X speedup over CPU implementation





Due to the algorithm's complexity, huge CPU time – matter of days- is required to process a typical seismic dataset on an interpretation workstation. This is not compatible with the interactive nature of interpretation. GPU computing largely reduces the required time and allows GCC to be used on a daily basis by interpreters.

Experimental Setup

- Interpretation Workstation
  - Intel Westmere (2 sockets X 6 cores), 2.94GHz, 48Go RAM
  - Fermi C2075 6 Go RAM 448 CUDA cores. Cuda 5
- Performance reported for Test Dataset : 2Go 1024 (Inline) × 1024 (Xline) × 512 (time) in single precision float format
- Cross-correlation based attributes CPU parallel implementation : 2 MPI processes X 6 OpenMP threads - Smoothing implementation is sequential

References

Ian T. Young et Lucas J. van Vliet (1995) Recursive implementation of the Gaussian filter. Signal Processing, 44(2):139 – 151
Bahorich, M., & Farmer, S. (1995). 3-D seismic discontinuity for faults and stratigraphic features: The coherence cube. The leading edge, 14(10), 1053-1058
Keskes, N.(2012). Gradient Coherency Cube (GCC) – TOTAL S. A. Patent number: EP12306380.2, Submission Date: 08.11.2012

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