Body-Wave Extraction and Tomography for Earthquake Research: A Collaboration Case Study between Stanford University Department of Geophysics and Supermicro

Problem Statement

Stanford University Department of Geophysics and Supermicro have collaborated together to help in Earthquake Research. Stanford Researcher Dr. Nori Nakata obtained high resolution seismic images (Figure 1: 3D velocity structures) from purely passive data (ambient noise) for the first time using Superworkstation 7047GR-TRF (Figure 2). Typically seismic imaging at this scale (~10km) using passive ambient noise data requires clusters of Supercomputers and months of processing time but Dr. Nori Nakata was able to achieve such results in just weeks using Superworkstation 7047GR-TRF.

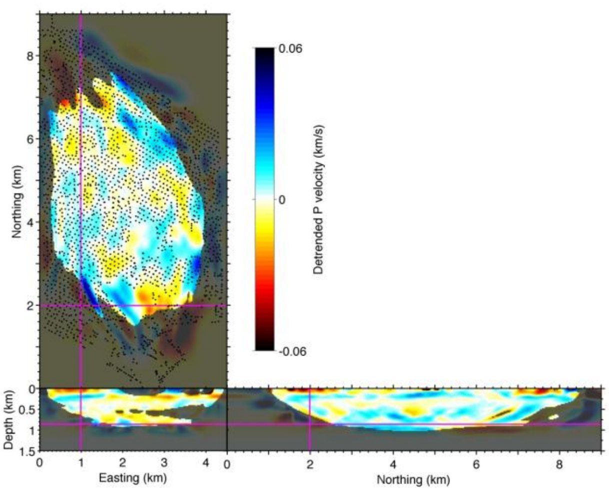

Figure 1 - Body Wave Extraction and Tomography from Ambient Noise Data

Method

Stanford's research retrieves diving P waves by applying seismic interferometry (Wapenaar, 2004; Draganov, 2009) to extract body waves to construct 3D seismic velocity with tomography (Hole, 1992). Typically, active sources must be used to obtain subsurface images but using Superworkstation 7047GR-TRF (1 TB of DDR3 memory capacity and 48 cores) Stanford was able to apply new body wave extraction filters and algorithms to the very large seismic datasets. This is the first application of body-wave tomography in the regional scale (~10 km) ambient noise. The ambient noise is recorded by a dense and large network (figure 2) which has about 2500 receivers with 100-m spacing. The data size is over 50 TB because it is from continuous recording and requires both computational speed (48 cores) and very large DDR3 memory capacity (1 TB) to analyze it.

Figure 2 - 7047GR-TRF

Data set and signal processing

Ambient-noise data were observed by Nodal Seismic from January 2012 at Long Beach and continuously recorded for about three months. The array is uniquely dense (100-m spacing) and large (2500 receivers) for continuous recording. The receivers have only a vertical component, and hence our target is P waves propagating between each receiver pair. The black dots on Figure 1 shows receiver locations. The receivers are almost evenly distributed over an area of 8 x 4.5 km^2.

Superworkstation 7047GR-TRF

Superworkstation 7047GR-TRF has 48 cores and 1TB of DDR3 memory. The number of cores speeds up the processing because Dr. Nakata's algorithms are all parallelized using OpenMP and MPI. However, the 1 TB of DDR3 memory capacity is the key factor in achieving speedup for this study. Because Stanford uses continuous seismic data and employs cross correlations, the dataset size is over 50 TB. When the dataset is re-sampled to 16 Hz and compute cross-correlation about 90% of computational time is occupied by reading/writing data. The 1 TB of DDR3 memory capacity of Superworkstation 7047GR-TRF decreases the computational time because Stanford can mount larger data to memory (in this case, Stanford mounts 800-GB data at once and use 200 GB for processed data). Once Stanford mounts the data, they compute cross-correlation in parallel using multi-core CPUs. In this way, Stanford is able to compute over 20 times faster than traditional workstations.

For filters, the benefits of large DDR3 memory capacity (1 TB) are even more significant because they need to mount all data in each bin to memory. The trace numbers, as well as the data size, are different in each bin, and the average size is about 100 GB, which is not mountable for regular workstations. If Stanford cannot mount all data in a bin, the quality of filter will decrease. Note that Stanford also needs to have memory space for output, which is about the same as the input size. Because of the memory capacity of Superworkstation 7047GR-TRF, Stanford can apply the filters near real-time without degrading the quality of filters.

Conclusion - Scaling Out

Stanford will be able to scale out their seismic algorithms, filters and research to even larger datasets using the 6 TB of DDR3 memory capacity offered on SuperServer 4048B-TRFT.

Figure 3 - SuperServer 4048B-TRFT

Using SuperServer 4048B-TRFT, Stanford will be able to study earthquakes on a scale and level of detail never seen before. Going forward, the computational speed of Stanford's algorithms combined with Supermicro hardware will enable a deeper understanding of causation and, most importantly, help in the prediction of earthquakes on a global scale.

Reference:

Draganov, D., X. Campman, J. Thorbecke, A. Verdel, and K. Wapenaar, 2009, Reflection images from ambient seismic noise: Geophysics, 74, A63-67.

Hole, J. A., 1992, Nonlinear high-resolution three-dimensional seismic travel time tomography: J. Geophys. Res., 97, 6553-6562.

Wapenaar, K, 2004, Retrieveing the elastodynamic Green's function of an arbitrary inhomogeneous medium by cross correlation: Phys. Rev. Lett., 93, 254301.