An implementation of the acoustic wave equation

MAXELER Technologies

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About the Authors

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Summary

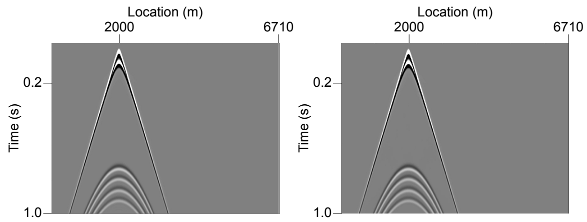
This study investigates the use of dataflow engines (DFEs) to accelerate an acoustic isotropic modeling application. Us-ing a Maxeler MAX2 PCI Express x16 DFE, we have achieved speedups of 2 *orders of magnitude* when compared to a single-core implementation on a modern CPU.

The acoustic modeling application in consideration is 3D finite difference, with 4th-order in time, 12th order in space, and uses single-precision floating-point arithmetic. Input data consist of two 3D earth model arrays (velocity and density) and a source function. The application iterates for a number of time steps with three wavefield arrays.

Total memory requirement on the CPU is therefore to store 4-bytes per point, for 5 arrays, or $20 * N^3$, where N is a spatial dimension. Since acceleration has the biggest impact for large projects, we assume that any solution should work for model sizes of $N = 1000$, with a total memory of 20 GB or more.

The acoustic variable density modeling code contains a kernel which consumes the majority of the compute cycles, indicating that the algorithm is a good candidate for acceleration.

We started the effort by studying the runtime performance of the application on CPUs. For a 300^3 mesh run on the AMD Opteron, the portion of runtime not contained within the kernel is only 0.04%. The kernel itself can be broken down into 5 subcomponents, which can be considered separately for acceleration.



(a) CPU (b) DFE

Figure 1: Comparison of the modeled seismograms between the CPU and the DFE implementations.

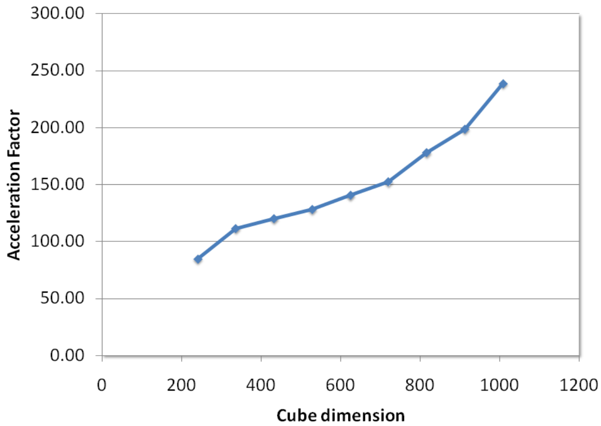


Figure 2: Acceleration over a Single Core CPU Implementation.

Figure 1 shows the results of testing a 2-layer, 3D model, with $672*672*256$ grid size. Seismograms were calculated both on a CPU using the reference modeling code (a) and on the DFEs using the DFE implementation (b).

The velocities of the 2 layers were 1500 and 4000 m/s and the density contrast was 1:4. The source was placed at location (2000m, 500m) and the receiver line was placed at depth of 550 m. The modeling parameters were a grid size of 10 m, peak frequency of 32 Hz and 643 time steps.

Figure 2 shows a performance comparison for several different sizes of cube between the DFE implementation and the reference software running on a single core of an Intel Xeon clocked at 2.66GHz. The DFE provides a speedup of nearly 250x over a single core for a large cube.

The implications of these results are twofold:

- Non-standard HPC technologies, such as DFEs can play a useful role in seismic data processing.
- The traditional notion of what is computationally cheap or expensive can be severely altered with the emerging new hardware and software technologies.