Hybrid FFTs on Heterogeneous CPU/GPU Computers

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The implementation of Fast Fourier Transform (FFT) has achieved great efficiency on Graphics Processing Units (GPU). However, prior FFT works on GPU use only GPU to compute, but employ CPU as a mere memory-transfer controller. The computation power in today's high-performance CPU is wasted. In this paper, a hybrid optimization framework is proposed to use both CPU and GPU in heterogeneous CPU-GPU systems to compute large scale 2D and 3D FFTs that exceed GPU memory. This computational model generalizes a partitioning scheme that efficiently distributes work to GPU and CPU to make them execute FFT computation load concurrently. Additionally, our approach integrates several FFT decomposition paradigms to tailor the extraction of computation and communication patterns for CPU and GPU, and in the process exploit more hidden parallelism than other heterogeneous methods to more fully utilize parallel computing resources. In order to attain the best performance, work distribution between GPU and CPU is tuned to achieve an optimal ratio of loading. We carry out a series of empirical profiling for FFT problems with different characteristics on GPU and CPU, and we develop effective heuristics to guide the entire balancing process. Our library also overlaps data transfers for increasing PCI bus bandwidth and equally importantly maintaining data and layout consistency between CPU and GPU. We evaluate the hybrid FFT library from three aspects, i.e., optimal load distribution ratios, running time, and normalized Root-Mean-Square Error (RMSE). In particular, the library is compared with CPU based library FFTW and Intel MKL. On average, our large FFT library of single precision on a heterogeneous computer comprised of a GeForce GTX480 GPU and an Intel i7 CPU is on average 41% and 93% faster than the 4-thread SSE-enabled FFTW and the 4-thread SSE-enabled Intel MKL, respectively. The accuracy of single precision measured by normalized RMSE is in the range from 3.9E–7 to 6.59E–7.