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Algebraic computations in seismology on GPU-clusters

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Recent advances in high-performance computing have allowed scientists to increase the speed of scientific computations. One of these advances is Graphics Processing Unit (GPU) which is a many-core processor and multithreaded in high-performance computing. Algorithms that can be expressed as data parallel computations such as matrix processing, in which single instruction is executed for multiple data (SIMD) are especially suitable for performing on GPU. We present algorithms for LSQR (Paige and Saunders, 1982) and LSMR (Fong and Saunders, 2011) methods, executable on GPUs. The LSQR and LSMR are iterative methods for solving least squares problems that are usually used for solving inverse problems. These methods are based on Golub and Kahan's bidiagonalization process. The LSQR and LSMR give reliable results especially when problems involve the large and spars ill- conditioned matrices, such matrices can be found in seismic tomography. The most time-consuming operation in these methods is the sparse matrix-vector multiplication (SpMV). For efficient matrix storage as well as SpMV, we use a Compressed Sparse Row (vector) Format (Bell and Garland, 2008), that dedicates one warp (32 thread) to each row. The model resolution matrix illustrates how well estimated model parameters fit the true model parameters. Although some researchers tried to approximate a generalized inverse for LSQR method, this method does not explicitly compute generalized inverse. Therefore it cannot be clearly used to calculate resolution matrix. However, following Yao et al. 2001, it is possible to determine resolution matrix by N times implementing LSQR independently. Therefore, we can utilize the Map-Reduce idea in our algorithm for computation of the model resolution matrix on GPU-clusters. Map-Reduce paradigm was popularized in 2004 by Google's researchers Dean and Ghemawat. Our algorithm is based on the Map-Reduce of Mohammadzaheri, et al. 2012, which consists of two main functions: Map and Reduce. Here, Map function is responsible for solving one or more equations of LSQR or LSMR and Reduce function summarizes all the Maps results. In fact output of Reduce is the resolution matrix. Although our algorithm is implemented on GPU-clusters, the Map-reduce idea for resolution matrix can also be performed on single and Multi-GPU.