Accelerating Elecromagnetic FEM Computations Using CUDA

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Finite Element Method is an efficient and versatile method which is often applied to the solution of boundary value problems that arise in electromagnetics. In order to achieve satisfactory accuracy, finer meshes, as well as higher-order FEM elements, need to be applied which both increase the numerical cost.

In order accelerate the complete FEM algorithm on GPUs (Graphics Processing Units) compatible with CUDA (Compute Unified Device Architecture) new massive parallelized algorithms have been developed for the finite-element matrix-generation and iterative solution of resulting sparse linear systems as well as for eigenvalue problems using a single or multiple GPUs.

In particular new strategies that allow generation of large very sparse matrices sand solving large systems will be discussed. A significant reduction of the time taken by matrix generation was achieved thanks to the parallelization of computations in numerical integration step (finite elements processed in parallel manner, parallelized Gaussian quadrature, parallelized dense matrix multiplications) and in matrix assembly step (i.e. new fast and parallel algorithm designed for conversion between matrix representation formats). For the solution of a linear system a hybrid GPU-CPU implementations of the conjugate gradient method with a V-cycle multilevel preconditioner in using single or several GPUs were developed. The iterative solver employs a new sparse matrix storage format which allows an efficient implementation of a sparse matrix-vector product on a GPU and achieves better performance than CUSPARSE library (CUDA 7.0) provided by NVIDIA Co. was proposed and implemented.

Numerical tests indicate that the FEM analysis accelerated with a GPU allows for acceleration of the FEM analysis by a factor of 10.1 for the largest test problem. This work was supported by the Polish National Science Centre under Contract DEC-2014/13/B/ST7/01173