§34. Development of Solver for Large Nonlinear Differential Equation and their Engineering Application

Ikuno, S. (Tokyo Univ. of Technology), Nakamura, H., Kamitani, A. (Yamagata Univ.), Saitoh, A. (Yamagata Univ.), Itoh, T. (Nihon Univ.), Takayama, T. (Yamagata Univ.), Hano, N. (Univ. Tokyo), Nagao, Y. (JCHO Osaka Hospital)

i) Introduction The large scale linear systems appear in discredizing process of nonlinear problems for various types of physical and engineering simulation. Especially, the time-dependent integro-differential equation should be numerically calculated in the shielding current density analysis of High Temperature Superconductor (HTS). The equation is discredized by Finite Element (FEM) Method and the completely implicit method, and the large scale linear system must be solved in each time step. It is known that the most of the calculation time spends for the solving the linear system [1, 2].

As is well known that a singular coefficient matrix is obtained from discretizing electromagnetic phenomena using FEM with edge elements. And a singular solution should be calculated. Frequently, the preconditioning Krylov subspace methods are adopted for the problem. In the previous study, we have implemented the Variable Precondition (VP) Krylov subspace method with mixed precision on Graphics Processing Unit (GPU) and Many Integrated Core (MIC), and investigated the performance of the method. However, the performances of both devices were not compared.

The main purpose of the present study is to implement the mixed precisioned VP Krylov subspace method on GPU and MIC, and to reduce the calculation time of the system. In addition, the performances of both devices are investigated [3].

ii) GPU and MIC Reciently, a clock frequency of CPU has gone as far as it can go, and a multi-core processor and an accelerator such as GPU are adopted for high performance computing calculations. In the GPU programming, the simulation code should be parallelized by Compute Unified Device Architecture (CUDA) or parallelized Application Programming Interface (API) such as Message Passing Interface (MPI). However, GPU programming cost using CUDA becomes very high. Many Integrated Core (MIC) architecture appears as a coprocessor on the scene of high performance computing, and about 60 cores are implemented on unit device. Since these cores are x86 architecture, the ordinal program code that developed on CPU can be implemented on MIC without transcribing, and very easy to parallelized by using OpenMP.

Both of GPU and MIC becoming cheaper and easy to construct high-performance computer cluster. Thus, the parallelization technique should be adopted for the numerical simulation actively to fulfill the huge scale simulation, and the high performance numerical investigation of electromagnetic field using GPU/MIC increase recently.

iii) Results and Discussions In the GPU evaluation, four GPUs are employed in unit node, and each node is connected by Infiniband Network. On the other hand, the symmetric mode and native mode are employed for multi-MIC calculation, and the concerted calculation between CPU and MIC is implemented. Processes are assigned to two CPUs and two MICs in the unit node on the symmetric mode, and processes are assigned to two MICs on the native mode. In addition, not only the communication between nodes but also between MIC in case of the native mode are achieved by using MPI [3].

The communication time and the calculation time of Variable Preconditioned Conjugate Gradient (VPCG) on multi-GPU and multi-MIC are evaluated. The results of computation show that the computation time decrease as the number of process increase in both cases. On the other hand, the communication time increase drastically as the number of process increase. Furthermore, the total execution time of GPU cluster is much better than that of MIC, and the time of the symmetric mode and the native mode is almost same. This result is caused by the architectural issue of MIC. In the GPU cluster, data communicate by mainly CPU, whereas the MIC is contracted for the most of all the communication in the MIC cluster. Additionally, GPU parallelization has a concept of WARP. Although almost all the communication of MIC to MIC or MIC to CPU cannot be controlled, the communication between CPU to GPU or GPU to GPU can be controlled by WARP explicitly. From this reason, the communication performance of MIC is more degraded comparing with GPU.

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3) S. Ikuno, Y. Hirokawa, and T. Itoh: "Acceleration of Iterative Solver for Electromagnetic Analysis using GPU/MIC", Proc. of Int. Conf. on the Computation of Electromagnetic Fields (COMPUMAG) 2015, Montreal, Jun. 2015.