§36. Development of a Portable AMR Module

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Adaptive mesh refinement (AMR) technique is an effective approache to enable a high-resolution simulation which is prerequisite to study complex and dynamic behaviors of hot plasma and understand detailed physics of small-scale events such as saturations of short-wave instabilities, micro-turbulence and magnetic reconnections. AMR technique is also suitable to construct a macro-scale model to predict long-time behaviors of the plasma because small-scale events often affect the long-time behaviors through changing local pressure gradients and/or magnetic configurations.

We have been developing an AMR module which is easily ported to various numerical codes, especially for the Numerical Simulation Research Project (NSRP) of NIFS. It is aimed to enable resolving the ion skin depth, the ion Larmor radius and some other scales locally in a fluid/particle simulation code by introducing the AMR module while macroscopic behaviors are also simulated simultaneously. The module is based on the block-based domain decomposition approach and the self-similar refinement. (See Fig.1.) The computational domains generated as a consequence of the refinement are distributed on the computational nodes according to the Morton method[1)], being connected to each other by the use of the Fully-Threaded Tree (FTT) structure.

The module is designed so that it can achieve relatively high performance in various computational environments including the Plasma Simulator (HITACHI SR16000) in NIFS, Fujitsu FX10, Bull B510 and Cray XE5. We have carried out simulations of a test problem solving the advection equation

$$\frac{\partial u}{\partial t}+c\frac{\partial u}{\partial x}=0 \qquad (1)$$

by the use of the first-order upwind difference scheme. In Fig.2(a), the strong scaling in this test is shown. The number of grid points is set 51200×51200 in the coarsest level. By increasing the number of computational cores from 256 to 2048, the computational time becomes shorter. The strong scaling in Fig.2(a) is good for Cray XE5, Fujitsu FX10 and HITACHI SR16000, while the scaling for Bullx B510 show a rapid saturation of the acceleration in the large number of cores. In Fig.2(b), the weak scaling is shown. The test result shows a good scaling both for Fujitsu FX10 and HITACHI. Though the strong and strong scaling for Bullx B510 is not very good for Bullx B510, the scaling for the other type of machines are good. We consider that the portability of the AMR module is well established for these machines.

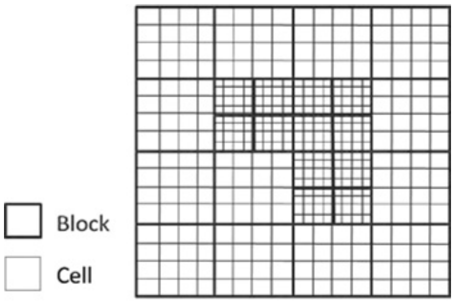

Fig.1. Concept image of the adaptive mesh refinement The mesh is refined when the numerical resolution should be improved.

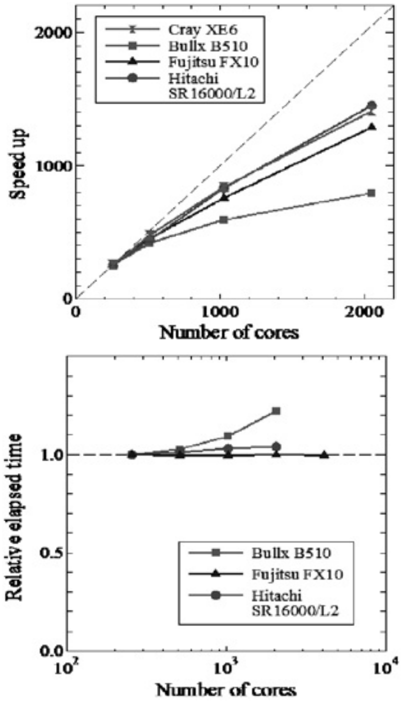

Fig.2 (a) Strong and (b) weak scaling in a test solving the advection equation by the use of the AMR module.

These results were reported in the 22nd International Toki Conference[2)] and JSST International Conference on Simulation Technology[3)].

1) Warren, M.S. and Salmon, J.K.: Proc. Supercomputing, IEEE, **12** (1993) 21.
2) Miura et al.: 22nd International Toki Conference (Nov.19-22, 2012, Toki, Japan).
3) Nunami et al.:JSST2012 International Conference on Simulation Technology (Sep.27-28, 2012, Kobe, Japan)