Parallel AMR Strategy for FDTD and Its Application in EMP Propagation over Large Area

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Abstract**—**FDTD method is an effective approach for electromagnetic pulse(EMP) problems solution. However, simulating EMP propagating in large area with conventional FDTD is not applicable, even with the state-of-art super-computers and proper parallel technology. We develop a parallel adaptive mesh refinement (AMR) strategy for FDTD to fulfill the requirement of EMP propagation simulation. Numerical examples show the AMR-FDTD method decrease the computation down to less than 20%.

Keywords- EMP, propagation, FDTD, AMR

I. INTRODUCTION

FDTD method is an efficient approach to solve electromagnetic pulse problems, since it solves Maxwell Equations in time domain[1]. However, conventional FDTD requires numerous meshing cells when implemented to large scale problems, such as EMP propagating in large area, even with the state-of-art super-computers and proper parallelization technology[2]. We develop parallel adaptive mesh refinement strategy for FDTD to fulfill the requirement of large scale EMP propagation simulation.

II. AMR-FDTD METHOD AND ITS PARALLELIZATION

The AMR strategy is based on the dynamic nature of the electric and magnetic fields in FDTD simulation process. For EMP propagation problems, the fields will concentrate in limited zone for a limited time period, in which a fine mesh is necessary to preserve the computation accuracy. The fine mesh will cover the field zone and track it dynamically while the pulse propagation. While in other zone, a coarser mesh will provide adequate accuracy since the electromagnetic field is weak or null.

The computation procedures for AMR-FDTD are as follows:
(1) update fields on coarse mesh level for one step;
(2) perform mesh refinement according to the space gradient of filed quantities, and fill the field on fine mesh by interpolation of field values on coarse mesh;
(3) update fields on fine mesh level with local time step for several steps, until time equals to coarser mesh level time;
(4) correct the fields on coarser mesh by interpolation from values on fine mesh;
(5) do step (2) to (4) recursively if there is more than one fine mesh level;
(6) return to (1) if not reach the FDTD termination criteria.

A hierarchical data structure which contains four levels: cell, *patch*, sub-domain and domain, is performed to organize the AMR operations as well as the parallel computation.

Domain Decomposition Method has been proven to be an efficient way to parallelize FDTD computation. However, the AMR operation breaks the computation workload uniformity, and conduces to poor parallel efficiency. Dynamical balance technology is performed to overcome this issue. The *patch*, which is a rectangular block consisting of mesh cells, will be exchanged among processors to obtain a dynamic balanced workload distribution, based on periodically checking of workload on each processor.

III. NUMERICAL RESULTS

A. PEC Sphere Scattering

Scattering of a PEC sphere with diameter of 30mm is simulated. The frequency range is 0-2 GHz. The step size of coarse mesh is 7.6 mm. Two fine mesh level is used with (2, 2, 2) refinement ratio. The computation time is 475 seconds for AMR-FDTD and 2513 seconds for conventional FDTD. AMR-FDTD reduces the computation time down to 18.9%.

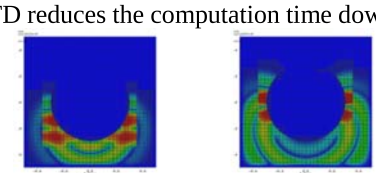
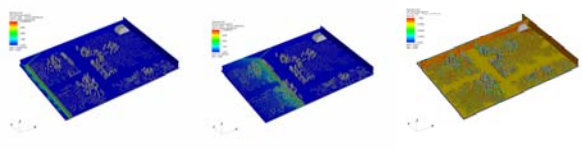


Figure 1. E-field and adaptive mesh of PEC sphere scattering.

B. EMP Propagation in City

The propagation in a city of EMP with frequency range from 0 to 100 MHz is considered. The dimension of the city is 6 km by 8 km by 0.2km. Conventional FDTD method would cost 1200 billion mesh cells. AMR-FDTD costs a mesh with a top of 3 billion cells to complete this simulation.



(a) (b) (c)

Figure 2. (a)(b) Transient E-field at different time
(c) E-field distribution at 5 MHz.

REFERENCES

[1] A. Valcarce, G.D.L. Roche, L. Nagy, J.F. Wagen and J.M. Gorce, “A new trend in propagation prediction,” IEEE Vehicular Technology Magazine., vol.6, no.2, pp.73-81, June 2011.
[2] Li H, Zhou H, Liu Y, et al., “Massively parallel FDTD program JEMS-FDTD and its applications in platform coupling simulation,” IEEE International Symposium on Electromagnetic Compatibility (EMC Europe), 2014: 229-233.