Performance Evaluation of Acoustic FDTD(2,4) Method Using Distributed Shared Memory System mSMS

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ABSTRACT

In this study, the performance of acoustic finite-difference time-domain (FDTD)(2,4) method was evaluated by using a partitioned global address space (PGAS) runtime system mSMS. The results show that mSMS can achieve nearly ideal weak scaling performance on TSUBAME 3.0 and ITO supercomputer system.

KEYWORDS

FDTD method, PGAS, software distributed shared memory, acoustic field simulation.

1 INTRODUCTION

For efficient large-scale acoustic analysis, it is important to employ high-order FDTD method such as FDTD(2,4) method [2], which has second-order accuracy in time and fourth-order accuracy in space.

To improve the programming productivity in multiple-node environments, a PGAS language that provides a global view of programming can be used.

In this study, mSMS [1], which is page-based distributed shared memory system is used for multi-node implementation of FDTD(2,4) method, and the performance evaluation is presented.

2 NUMERICAL METHOD AND IMPLEMENTATION

The equations governing the acoustic wave in three dimensions are given by

$$\rho \frac{\partial \vec{v}}{\partial t} = -\nabla p$$

$$\nabla \cdot \vec{v} = -\frac{1}{k}\frac{\partial p}{\partial t}$$

where $\vec{v}$ is the particle velocity, p is the acoustic pressure, ρ is the density of the medium, k is the bulk modulus.

In FDTD(2,4) method, the spatial difference operator with fourth-order accuracy is used [2]. For example in the x-direction, it can be denoted by

$$\begin{aligned}\boldsymbol{d}_{4x} f^n(x,y,z) =& \boldsymbol{d}_{2x} f^n(x,y,z) + \frac{1}{24\Delta x}\left[3f^n\left(x+\frac{\Delta x}{2},y,z\right)\right.\\ &- 3f^n\left(x-\frac{\Delta x}{2},y,z\right) - f^n\left(x+\frac{3\Delta x}{2},y,z\right)\\ &\left.+f^n\left(x-\frac{3\Delta x}{2},y,z\right)\right].\end{aligned}$$

For the multi-node implementation with mSMS, a remote data preload API is used for halo exchange, which is an alternative to remote page fetching by SIGSEGV signal handler. OpenMP is used for intra-node parallelization.

3 PERFORMANCE EVALUATION

The performance evaluation was performed on TSUBAME 3.0 (Intel Xeon E5-2680 v4, 14 core, 2.4GHz × 2 / node, Intel Omni-Path 100Gb/s × 4, Intel MPI 2018.1.163) and ITO Subsystem A (Intel Xeon Gold 6154, 18 core, 3.0 GHz × 2 / node, InfiniBand EDR 4x 100Gb/s, MVAPICH2-X 2.2). The number of OpenMP threads is set to 24 in both architectures. The data are parallelized in the z-direction, and the mesh size is set to 1024^3 per 1 node with double precision.

Fig. 1 shows the weak scaling of a parallel FDTD(2,4) solver from 1 node to 32 nodes. The leftmost bars in Fig. 1 represent the baselines, i.e., the single-node execution times without using mSMS on each architecture. The ratios of the 2-32 nodes execution time to the baseline execution time determined using ITO-A and TSUBAME 3.0 are 1.07-1.16 and 1.09-1.30, respectively.

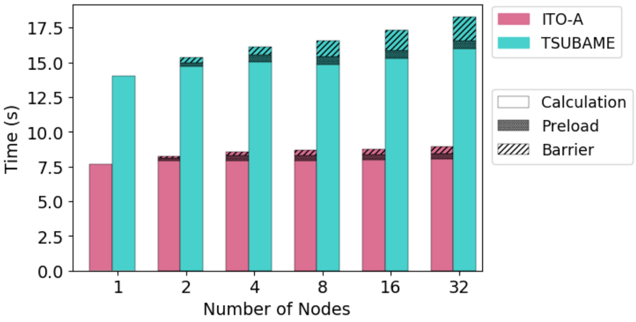

Figure 1: Weak scaling results (Average execution time per 10 simulation steps for 5 runs)

4 CONCLUSIONS

We presented nearly ideal weak scaling results of the FDTD(2,4) method parallelized with mSMS and OpenMP, in spite of using a straightforward implementation, which requires data exchange in every time step. In future works, incorporate spatial and temporal blocking to FDTD(2,4) method should improve the performance.

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REFERENCES

[1] Hiroko Midorikawa, Kenji Kitagawa, and Yugo Sakaguchi. 2019. mSMS : PGAS Runtime with Efficient Thread-based Communication for Global-view Programming. In *2019 IEEE International Conference on Cluster Computing*.

[2] Yuuki Sendo, Hironori Kudo, Tatsuya Kashiwa, and Tadao Ohtani. 2003. The FDTD(2, 4) method for highly accurate acoustic analysis in three-dimensional space. *Electronics and Communications in Japan (Part III: Fundamental Electronic Science)* 86 (11 2003), 30 – 37. https://doi.org/10.1002/ecjc.10076