Development of distributed parallel explicit Moving Particle Simulation (MPS) method and zoom up tsunami analysis on urban areas

Kohei MUROTANI,
Seiichi KOSHIZUKA
The University of Tokyo
Tokyo, Japan
muro@sys.t.u-tokyo.ac.jp

Masao OGINO
Nagoya University
Nagoya, Japan

Ryuji SHIOYA,
Yasushi NAKABAYASHI
Toyo University
Kawagoe, Japan

***Abstract*— In this research, a distributed memory parallel algorithm of the explicit MPS (Moving Particle Simulation) method is described. The MPS method is one of the popular particle method with collision. The ParMETIS is adopted for domain decomposition. We show the algorithm and the results of parallel scalability in our poster using the FX10 of the University of Tokyo. As the applications, a large-scale run-up tsunami analysis such as inundating the Ishinomaki urban area and carrying two 10m diameter tanks by the tsunami is done.**

Keywords—MPS method; Particle method; Tsunami; ParMETIS; Distributed parallel; Dynamic load balance

I. Introduction

MPS (Moving Particle Simulation) method [1,2] is one of the popular particle methods with collision. The MPS method is a continuum by particles and solve the Navies-Storks equation. The MPS method define differential operator of interactions between particles and calculates states of particles. The MPS method is easy to calculate dynamic physical phenomena such as free surface flow and large deformations. On the other, the motion of the particles as calculation points on time marching processes is difficult to parallelize the particle method in distributed memory parallel computers.

In this research, we describe our developing distributed memory parallelization of the MPS method using ParMETIS [3] to solve realistic large scale tsunami analysis. We show the results of tsunami analysis for the Ishinomaki urban area by the Great East Japan Earthquake on March 11th, 2011.

II. Parallel Algorithm

First, a bounding box of an analysis region is partitioned to buckets as shown in Fig. 1. The width of a bucket is defined as an influence radius of interactions between particles. All particles are assigned to the buckets. In Fig. 1, circles are particles.

Next, domain decomposition is performed using the ParMETIS by the buckets and particles are assigned to each subdomain as shown in Fig. 2. In Fig. 2, colors of buckets correspond to subdomains. The particles in the subdomains are assigned to corresponding processor element (PE). Since the ParMETIS give minimal-cut partitions of graphs and meshes in parallel, the graph with vertices weighted by the number of particles in corresponding buckets is partitioned by the ParMETIS. As the result, the number of particles in each subdomain become almost equal and the size of interfaces among subdomains become almost minimum.

Each decomposed region is expanded from the boundary by one bucket in width called as halo area as shown in Fig. 3. The particles in expanded regions are assigned to one PE. If an imbalance in the number of particles among regions appears, the domain decomposition is done again in order to recover the balance of the number of particles.

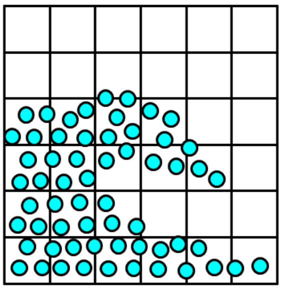


Figure 1: Assigning particles into buckets

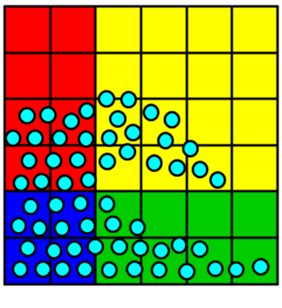


Figure 2: Domain decomposition for buckets

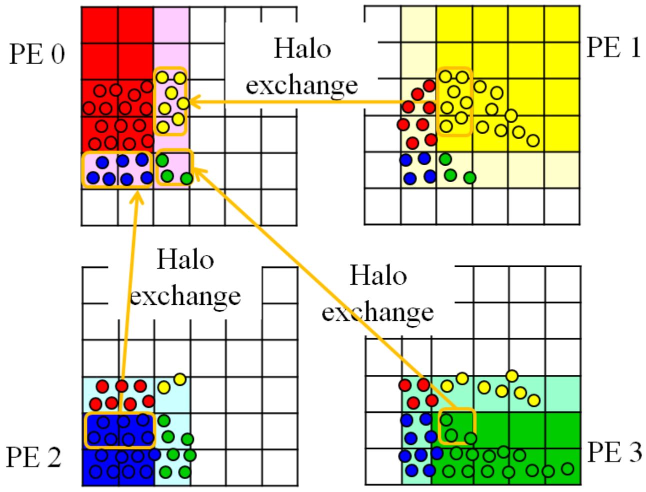


Figure 3: Halo exchange pattern

III. TSUNAMI ANALYSIS WITH FLOATING OBJECTS

We calculated the tsunami analysis such as inundating the Ishinomaki urban area and carrying two 10m diameter tanks by the tsunami. We performed the zoom-up analysis between the Ishinomaki seacoast area (4.0km x 3.5km) and the Ishinomaki urban area (400m x 550m). The inlet boundary condition on the Ishinomaki seacoast area is presented by Tsunami Engineering Laboratory of Tohoku University and KOKUSAI KOGYO CO., LTD. This inlet boundary condition is the result of simulation of the Great East Japan Earthquake using the shallow water equation.

Figure 4 is the result of the tsunami analysis for the Ishinomaki seacoast area. Let the diameter of a particle be 1 m. About 7 days were required for this analysis of 800 sec using 144 PEs of the FX10 at the University of Tokyo. The maximum number of particles was 260 million. The wall-clock time of one time step is an average of 5.5 sec.

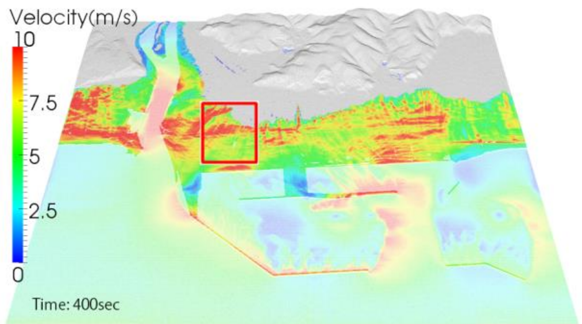
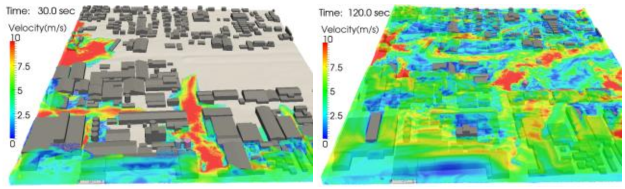


Figure 4: Tsunami analysis for the Ishinomaki seacoast area

Next, inlet boundary conditions for the Ishinomaki urban area in Figure 4 are generated along red lines in Figure 3 for zoom-up analysis. Let the diameter of a particle be 0.5 m. About 6 hours were required for this analysis of 200 seconds using 600 PEs of the FX10 at the University of Tokyo. The maximum number of particles was 40 million. The wall-clock time of one time step is on average 0.25 seconds. The Courant number is 0.1. In this analysis, the event whereby two 10m diameter tanks were carried along by the tsunami is simulated. The two tanks are regarded as rigid bodies. This analysis is a problem of weak coupling due to the interplay between rigid bodies and fluid using the procedure in [2].



(a) at 30 sec (b) at 120 sec

Figure 5: Tsunami analysis for the Ishinomaki urban area

IV. CONCLUSION

In this research, a distributed parallel explicit MPS algorithm of the bucket-based domain decomposition was developed. We applied our developing method to tsunami analyses, such as one on the inundation of the Ishinomaki urban area by the tsunami resulting from the Great East Japan Earthquake. In future, we will solve realistic disaster prevention problems and engineering problems using the developed method.

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