Development of Explicit Moving Particle Simulation Framework and Zoom-Up Tsunami Analysis System

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ABSTRACT

In this research, we are developing LexADV_EMPS which is the Explicit Moving Particle Simulation (MPS) [1] framework. The LexADV_EMPS supports "Domain decomposition", "Halo exchange" and "Dynamic load balance" as parallel computing functions for particle methods of the continuum mechanics. We have been able to solve large scale realistic tsunami analysis using distributed memory parallel Explicit MPS method [2] implemented by the LexADV_EMPS. Today, Ishinomaki city, Kesennuma city and Fukushima Daiichi Nuclear Power Station have been successfully solved by our system using K computer of RIKEN, FX10 of the University of Tokyo and CX400 of Nagoya University.

Keywords

LexADV_EMPS, Open source software, MPS method, Particle method, Tsunami, ParMETIS, Distributed memory parallel, Domain decomposition and Dynamic load balance

1. INTRODUCTION

We have been developing the open source CAE software, named ADVENTURE, which is a general-purpose parallel finite element analysis system and can simulate a large-scale analysis model with various supercomputers. Our aim in this research is to develop scientific libraries for the post peta-scale simulation by the "particle methods" for the continuum mechanics.

The particle method regards a continuum as a set of particles, discretizes the physical laws governed by differential equations using interactions between the particles, and calculates the states and motions of the particles. Since the particles, as the calculation points, move on the time-marching processes, the particle method is superior to grid methods in terms of solving dynamic physical phenomena such as free surfaces and large deformations. However, the motion of particles makes it difficult to parallelize the particle method in distributed memory parallel computers.

We adopted the Moving Particle Simulation (MPS) method which is one of the most popular particle method as target solver and have been developing the LexADV_EMPS of the Explicit MPS framework which supports functions for parallel computing.

2. LexADV_EMPS

LexADV [3] is free and open source software for large-scale numerical simulations of continuum mechanics problems. Currently, some beta version software was released. LexADV_EMPS v0.1b released as Open Source Software on Oct. 2014 is the Explicit Moving Particle Simulation framework to solve large scale problems by particle methods. Therefore, target problem size is 10 million to 1 billion particles or more than. The LexADV_EMPS is supporting three functions of "Domain decomposition", "Halo exchange" and "Dynamic load balance" required in distributed memory parallel computing of particle methods. The LexADV_EMPS implements efficient data management by adopting hierarchical bucket structure of three levels. In development and operating environment, OS is UNIX or Linux, compiler is C language and communication Library is MPI.

3. ZOOM-UP TSUNAMI ANALYSIS SYSTEM

Tohoku area was severely damaged by the tsunami of the Great East Japan Earthquake on 2011. Our target is to simulate impact by three kind of tsunami analyses on urban areas of Tohoku area. First, tsunami is running-up in urban area and inundates into a building. Second, floating objects have collisions with each other and buildings. Third, stress of buildings from fluid pressure is estimated.

Zoom-up tsunami analysis system have been built in order to solve our target problems. In our system, zoom-up analysis by three stages analyses is adopted to solve a large area from an epicenter to an urban area. In the first stage, the two-dimensional shallow-water analysis is solved in the area of about 1000 km x 1000 km from the epicenter to the coastal areas. In the second and third stages, the three-dimensional tsunami run-up analyses are solved for the coastal areas using the distributed memory parallel Explicit MPS method [2] implemented by LexADV_EMPS. Today, Ishinomaki city, Kesennuma city and Fukushima Daiichi Nuclear Power Station have been successfully solved by our system.

K computer of RIKEN, FX10 of the University of Tokyo and CX400 of Nagoya University have been used in our system. For example, in case of Kesennuma city, tsunami run-up analysis with a large ship of 60m in total length as shown in Fig. 1, analysis of 130 million particles (1m particle spacing) and 1800 seconds has been done by K computer 12000 nodes and total wall-clock time 30 hours.

Figure 1. Tsunami run-up analysis on Kesennuma city with a large ship of 60m in total length

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5. REFERENCES

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[3] LexADV website, http://adventure.sys.t.u-tokyo.ac.jp/lexadv/