STT55-01 Room:103 Time:May 27 14:30-14:45

Advanced Disaster Simulation Researches on Earthquakes and Tsunamis using High Performance Computing System Kei

KANEDA, Yoshiyuki[1*] ; FURUMURA, Takashi[2] ; IMAMURA, Fumihiko[3] ; HORI, Muneo[2]

[1]Disaster mitigation research center, Nagoya University, [2]Earthquake Research Institute, University of Tokyo, [3]International Research Institute of Disaster Science, Tohoku University

'Kei' computer is one of the highest computing system in the world. Using 'Kei' computer, we are performing the advanced simulation for disaster mitigation by earthquakes and tsunamis in a project 'Study for Advancement of Prediction Accuracy on Earthquake and Tsunami'. In this research project, we have three research fields as Earthquake simulation research field, Tsunami research filed and Damage estimation research field.

In Earthquake simulation research field, we are developing the scenario simulations of earthquake recurrences on the subducting plate around Japan. As other earthquake simulation researches, we are simulating seismic waves based on the scenarios, and the underground structures using seismographs.

The second research simulation research field on Tsunami hazard, we are developing applications for the simulating tsunami damages at East Japan earthquake 2011. In this research field, not only damage simulations, but also we are developing the early tsunami detection system using simulation and real time data. Finally, we will apply it to the Nankai trough seismogenic zone and etc.

The third research field is the civil engineering research as the adavanced civil engineering structural analyses, seismic response analyses on large scale cities, and agent simulation for more precise and practical evacuations.

Finally, we will integrate these research fields in this project for the seismic simulator on disaster mitigation.

Keywords: high performance computing, disaster mitigation, simulation, earthquake, tsunami

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

STT55-02 Room:103 Time:May 27 14:45-15:00

Earthquake Simulations running on K computer

ICHIMURA, Tsuyoshi[1*]

[1]Earthquake Research Institute,The University of Tokyo

Large-scale high fidelity model can be constructed with recent accumulation of spatial data. Although computational cost of earthquake simulations using such model is huge, supercomputer (e.g. K computer) is now resolving difficulties and creating new frontier in this field. In this presentation, recent illustrative examples (crust deformation, earthquake ground motion, soil amplification, city response etc.) will be shown.

Keywords: Simulation, High performance computing, Computational science

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

STT55-03 Room:103 Time:May 27 15:00-15:15

Development of high performance particle simulations of fluid and granular dynamics for contributing to human society

NISHIURA, Daisuke[1*] ; FURUICHI, Mikito[1] ; SAKAGUCHI, Hide[1]

[1]JAMSTEC

Large-scale parallel computing is important for numerically reproducing actual measurement results and dynamics of phenomena in various science and engineering areas, such as civil engineering, bioengineering, and earth sciences. The computational performance of parallelized software tools plays a critical role in such simulation studies, as these improve the computational accuracy relative to the simulation resolution within a limited computation time. Recent massively parallel computer systems based on shared- and distributed-memory architectures employ various types of arithmetic processors. Current processor designs are known to exhibit totally different computational performance depending on the numerical algorithms and implementation methods employed. Currently, parallel computing generally uses either a multi-core CPU, graphics processing unit (GPU), or many integrated core (MIC) processor. Multi-core CPUs have traditionally been used in high-performance computing, whereas GPUs were originally designed for computer graphics with many arithmetic cores. The common progress of current processor designs is the increase in the number of cores using vector operations such as single-instruction?multiple-data (SIMD). In such a situation, the shared-memory parallelization plays a basic but critical role in dealing with the increasing number of arithmetic cores in an efficient manner.

Numerical simulation methods used in science and engineering include the finite difference method (FDM), finite element method (FEM), finite volume method (FVM), boundary element method (BEM), and particle simulation method (PSM). Among these, PSM has a benefit of being mesh-free, allowing the computation of large-scale deformations and fractures of a continuum body without expensive remeshing tasks. As a PSM, smoothed particle hydrodynamics (SPH) is often used for tsunami disaster simulations because of its robustness in free-surface fluid dynamics. The discrete element method (DEM) is one popular PSM for granular dynamics in which geometrical size and shape attributes are provided for each particle. In the most conventional formulation of the DEM, the Voigt model in both the normal and tangential directions is considered at each contact point. In the tangential direction, Coulomb friction is introduced to determine the maximum tangential force and the slip condition. In addition, rolling friction can be considered at the contact points. Therefore, the DEM is attractive to simulate granular materials such as sand, pebbles, and other grains.

However, PSM programs must be implemented carefully to avoid write-access conflicts under shared-memory parallelization, especially when calculating a resultant force. In addition, it is important for distributed-memory parallelization to dynamically balance the computational load between computational nodes. To address these issues, we have proposed parallel algorithms that use the action-reaction law and parallelize the interaction summation with a reference table to avoid memory access conflicts. We have also implemented the algorithm of dynamic load balancing by resizing the domain decomposition region. Our methods were implemented on various parallel processors such as GPU, MIC processor, multi-core CPU on K computer, and vector processor on Earth simulator. In this presentation, we will talk about these parallel algorithms and applications for contributing to human society; Tsunami disaster simulations in consideration of structures?soil?fluid interactions and impact dynamics of ballast particles in rail track are important topics that require a high performance computing resources.

Keywords: DEM, parallel computing, Tsunami, ballast track, particle, SPH

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

STT55-04 Room:103 Time:May 27 15:15-15:30

Efficient Domain Partitioning Method for Dynamic BIEM applicable to Non-planar Faults

ANDO, Ryosuke[1*]

[1]School of Science, University of Tokyo

The boundary integral equation method (BIEM) is a powerful tool to analyze the earthquake rupture dynamics on non-planar faults. The non-planar fault analysis requires of the boundary integral equations (BIEs) that they are formulated in the real space and time domain, while those formulate in the spectral domain are limited to the application of the planar fault geometry. However BIEM in the space-time domain has extremely large numerical costs. Due to such large costs particular for the memory requirement, efficient use of the memory storage of the integration kernel have not be possible. In this study, we develop a new method to reduce the calculation time and memory requirement greatly without degrading the accuracy in 3-D. We extend the method proposed by Ando et al. (2007) in 2-D. This method divide the causality cone appealing in the integration kernel to the domains related to the wave fronts, the near-field term and the static term. We implement the algorithm on K-computer, and demonstrate the memory storage of the integration kernel becomes possible on the currently available computational environment owing to the reduced memory requirement. This contributes the efficiency of the numerical analysis considerably. For example, by using the same 6400 nodes, the analysis of the model consisting of 160 thousands fault elements and 1600 time steps took about a half year with the original method, however it is reduced to about two hours with the current efficient method. The current method is also shown to be scalable on distributed memory environment to the scale of these nodes. This method is expected to break through the emerging limitations of the dynamic earthquake rupture simulations with realistic 3-D geometrical models, and will contribute to widen the spectrum of the applicational works using the dynamic simulations.

Keywords: Boundary element method, Boundary integral equation method, non-planar faults, rupture dynamics, domain partitioning, high speed computing

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

STT55-05 Room:103 Time:May 27 15:30-15:45

Current status and issues of Tsunami simulation by HPC

ARIKAWA, Taro[1*]

[1]Port and Airport Research Institute

The Great East Japan Earthquake of 2011 has shown that a tsunami disaster is not limited to inundation damage in a specified region, but destruction over a wide area can cause a severe disaster. Because various structures stand on the land, in order to evaluate damage to these structures, it is necessary to perform highly precise evaluations of three-dimensional fluid motion. But the calculation cost of high precision three-dimensional fluid analysis is very high. So the goals of this research were to develop a method of coupling STOC (Tomita et al., 2005) and CADMAS-SURF/3D (Arikawa et al., 2005) to establish a method of efficiently calculating every stage from wave source to runup, and to verify its applicability.

Summing up shows that in order to improve overall calculation speed, as long as this method is adopted, the calculation domain of STOC-ML is as small as possible and CS3D is as large as possible, and it is important the number of calculation nodes be increased to the level eliminating synchronicity standby state.

Under this condition, calculation time is about 2s/step, and if the mesh is 1m wide, the time interval is an average of about 0.004s/step, so in order to calculate integration time of 1s, about 500s are necessary.

The coupling simulator with structure analysis is also shown. The breakwater under tsunami overflow was reproduced.

Finally, the issues of the future tsunami simulation will be discussed.

Keywords: Tsunami simulation, High performance computing, Tsunami, Coupling simulation

STT55-06 Room:103 Time:May 27 15:45-16:00

Two-phase flow simulation in the large digital rock by using high performance cluster

JIANG, Fei[1] ; TSUJI, Takeshi[1*]

[1]I2CNER, Kyushu University

A numerical implementation based on a Graphics Processing Unit (GPU) is proposed for the acceleration of the two-phase simulation using Lattice Boltzmann Method (LBM). The LBM yields regular, data-parallel computations; therefore, it is especially well fitted to GPU calculations. This study focuses on the application of the LBM for fluid displacement computations in real rock sample. For this purpose, the digital rock model is reconstructed from the micro-CT scanned images of reservoir sample with a resolution of 2.0 um. In order to obtain reliable and accurate results from the developed numerical model, the computational domain must be large enough to cover the representative element size (REV) of sample rock. As a result, pore scale LBM simulation of multiphase porous medium systems with sufficient resolution and large grid-number are very computationally challenging. To achieve this extremely large-scale simulation, multi-GPU parallel scheme by using CUDA and MPI is developed. Careful optimizations include sparse storage scheme, efficient domain decomposition and non-blocking communication are desired for algorithm implementation. Finally, we succeeded to perform a two-phase simulation with 10 billion (1000 x1000x1000) mesh sizes using a small-scale GPU cluster. The developed large-scale simulation method enables the direct upscaling from pore scale to core scale which is a very powerful tool for many engineering applications such as enhanced oil recovery (EOR) and Carbon Capture and Storage (CCS).

Keywords: Digital rock, lattice Boltzmann method, two-phase simulation, GPU, CO2 storage

STT55-P01 Room:Convention Hall Time:May 27 18:15-19:30

Introduction for Creating future of solid Earth science with HPC

HORI, Takane[1*] ; KANEDA, Yoshiyuki[2] ; HORI, Muneo[3] ; HINO, Ryota[4] ; ARIKAWA, Taro[5] ; TODORIKI, Masaru[6]

[1]JAMSTEC, [2]Nagoya University, [3]University of Tokyo, [4]Tohoku University, [5]Port and Airport Research Institute, [6]University of Tokyo

In this session we will explore the scientific and social issues that can be addressed by Earth scientists over the next 10-20 years using high performance computing (HPC). We will discuss future problems and prospects in the development of solid Earth science, especially for simulation technology in earthquake and tsunami disaster mitigation, new methods for big data analyses of seismic waves and crustal deformation obtained by high-density observation networks, construction of multi-scale solid Earth models, and so on. We welcome both earth scientists working on computational, observational and theoretical aspects of the physics of the solid Earth, and specialists on disaster mitigation, to discuss the role of HPC in solving future problems in this field. We will introduce current states in this talk.