STT55-01 会場:103 時間:5 月 27 日 14:30-14:45

地震津波の防災減災のための京コンピュータを用いたシミュレーション研究
Advanced Disaster Simulation Researches on Earthquakes and Tsunamis using High Performance Computing System Kei

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'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.

キーワード: ハイパフォーマンスコンピューティング, 防災・減災, シミュレーション, 地震, 津波
Keywords: high performance computing, disaster mitigation, simulation, earthquake, tsunami

STT55-02 会場:103 時間:5 月 27 日 14:45-15:00

京コンピュータを用いた地震のシミュレーション
Earthquake Simulations running on K computer

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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.

キーワード: シミュレーション, ハイパフォーマンスコンピューティング, コンピュテーショナルサイエンス
Keywords: Simulation, High performance computing, Computational science

STT55-03 会場:103 時間:5 月 27 日 15:00-15:15

ハイパフォーマンスコンピューティングにおける流体と粒状体に対する粒子法シミュレーションの進展と社会貢献的利用
Development of high performance particle simulations of fluid and granular dynamics for contributing to human society

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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.

キーワード: 離散要素法, 並列計算, 津波, バラスト軌道, 粒子, SPH
Keywords: DEM, parallel computing, Tsunami, ballast track, particle, SPH

STT55-04 会場:103 時間:5 月 27 日 15:15-15:30

3次元非平面断層解析に適した動的境界要素法の領域分割法による高速化
Efficient Domain Partitioning Method for Dynamic BIEM applicable to Non-planar Faults

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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.

キーワード: 境界要素法, 境界積分方程式法, 非平面断層, 動的破壊, 領域分割, 高速解法
Keywords: Boundary element method, Boundary integral equation method, non-planar faults, rupture dynamics, domain partitioning, high speed computing

Japan Geoscience Union Meeting 2015
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津波シミュレーションの現状と課題
Current status and issues of Tsunami simulation by HPC

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津波シミュレーションでは，波源から遡上までをマルチスケールで連成し，遡上計算部においては３次元シミュレーションを用いて計算する計算や，漂流物との連成計算，構造物の破壊計算との連成計算などの高精細な計算が，京コンピュータを用いてできあがりつつある．本稿では，その現状について整理をするとともに，津波シミュレーションの課題についてまとめるものである．
３次元の高精細シミュレーションにおいては，1m 程度の格子間隔で，およそ 10 億格子数を用いた計算が数万ノードのコンピュータを使用して計算できるようになった．その計算では，実時間の 500 倍から 1000 倍程度の計算スピードで計算することが可能となる．また，構造物との連成計算では，津波による防護施設の変形が実験と同じような精度で計算できるようになっている．
そのようななかで，今後の課題としては，被害の想定だけなく，復旧や復興の事前対策への活用といった社会との連携が必須であるが，そのためには，建築構造物の破壊やがれきの計算ということが必要なってくるが，そのような方向性について課題としてまとめる

キーワード: 津波シミュレーション, ハイパフォーマンスコンピューティング, 津波, 連成計算
Keywords: Tsunami simulation, High performance computing, Tsunami, Coupling simulation

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STT55-06 会場:103 時間:5 月 27 日 15:45-16:00

HPC を用いた巨大デジタル岩石内の２相間隙流体シミュレーション
Two-phase flow simulation in the large digital rock by using high performance cluster

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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).

キーワード: デジタル岩石, 格子ボルツマン法, ２層流シミュレーション, GPU, 二酸化炭素の地下貯留
Keywords: Digital rock, lattice Boltzmann method, two-phase simulation, GPU, CO2 storage