粒子法計算における動的負荷分散技術の開発：津波等の混相流問題の大規模計算にむけて
Parallel implementation of the particle simulation method with dynamic load balancing: Toward large scale simulation of geophysical system of mutiphase flow

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Fully Lagrangian methods such as Smoothed Particle Hydrodynamics (SPH) and Discrete Element Method (DEM) have been widely used to solve the continuum and particles motions in the computational geodynamics field. These mesh-free methods are suitable for the problems with the complex geometry and boundary. Moreover, their Lagrangian nature allows non-diffusive advection useful for tracking history dependent properties (e.g. chemical evolution) of the material. These potential advantages over the mesh-based methods offer effective numerical applications to the geophysical flow and tectonic processes, which are for example, tsunami with free surface and entrainment of sand, magma intrusion within a fracture of rock with crystals, and shear zone pattern generation of granular deformation.
In order to investigate such geodynamical problems with the particle based methods, over millions to billion particles are required for the realistic simulation. Parallel computing is therefore important for handling their huge computational cost. An efficient parallel implementation of SPH and DEM methods is however known to be difficult especially for the distributed-memory architecture. Lagrangian methods inherently have workload imbalance problem for parallelization with the fixed domain in space, because particles move around and change workloads during the simulation run. Therefore, dynamic load balance is key technique to perform the large scale SPH or DEM simulation.
In this presentation, we introduce the parallel implementation technique of SPH and DEM method utilizing dynamic load balancing algorithms toward the high resolution simulation over large domain using the massively parallel super computer system. Our method utilizes the imbalances of the executed time of each MPI process as the nonlinear term of parallel domain decomposition and minimizes them with the Newton like iteration. In order to perform flexible domain decomposition in space, the slice-grid algorithm is used. Numerical tests show that our approach is suitable for solving the particles with different calculation costs (e.g. boundary particles) as well as the heterogeneous computer architecture. We analyze the parallel efficiency and scalability on the super computer systems (K-computer, Earth simulator 3, etc.).

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