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Parallel Strategies of NET3D for High-Speed Impact Simulation

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Summary

In order to develop the efficient parallel high velocity impact code, there are some difficulties. First of all, a fine serial code which can simulate complicate contact should be prepared and contact parallelization is difficult due to its complexity. Moreover, large scale computing resources are required to evaluate and improve its parallel performance. *NET3D* code is based on Lagrangian scheme and especially focus on numerical simulation of brittle material. In this paper, we describe the contact parallel algorithm of *NET3D* code and then, evaluate the parallel performance with several applications such as tayler impact test, oblique metal sphere impact problem. The evaluation of parallel performance was conducted in self-made linux cluster, PEGASUS, which consists of 260 node (520CPUs) and Gigabit Network.

keywords: Parallel, High-Speed Impact, Penetration, Element Erosion.

Parallel Procedure of Net3D Code

Parallel contact-impact simulation procedure can be divided by domain partioning procedure, internal force calculation and contact treatment procedure. In order to divide the subdomain, graph partitioning scheme is used with METIS. In case of the internal force calculation, it carried out once at the domain partitioning procedure. However, the mesh structure is changed at the every time step when the case of element erosion scheme are used for penetration simulation and the amount of calculation of each CPU is unbalanced because the contact search domain size is getting bigger as the number of time step increase. Therefore, graph partitioning scheme is used again when the subdomain size is two times bigger than previous updated subdomain time step.

In order to calculte internal force, NET3D find out neighboring subdomains (or processor identification number) and makes neighboring sub domain list to communicate each other based on node index. And then it calculate internal force of element and node at inside subdomain as serial procedure. Using neighboring sub domain list, each processor exchanges and adds the internal force of the nodes at the subdoamin boundary. This procedure is shown in Fig.1 schemetically.

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Parallel contact force calculation is much more complicate than internal force calculation and requires much more amount of communication. It is shown Fig.2. NET3D uses the contact search domain based on subdomain divided at internal force calculation procedure for the parallel efficiecy. The size of contact search domain is ten percent bigger than subdomain along with x,y,z direction. After sharing the size of contact search domain of each CPU, the information required to communication is collected as same procedure at internal force calculation but the element index is used And then, the contact forces at node are calculated as serial procedure. Not like internal force calculation, the calculated contact forces are not exchaned because the contact search domains are duplicated. In other words, contact forces at node inside their own subdomain are only updated. In order to simulate penetration phenomena, the element erosion is often used. If there is no erosion element, the parallel procedure is much more simple because the connectivity information of mesh is same throughout the whole calculation. In order to overcom this difficulty, the whole mesh structure is stored as graph information at the begining of procedure and this graph information of erosion element is updated at each step.

Parallel Performance

With taylor impact test for internal force calculation and oblique metal sphere impact problem for contact force calculation, scalability test is conducted. Fig. 3 and Fig. 4 show the performance results. 544,885 elements model is used for internal force calculation and 546,489 elements model is used for contact force calculation. The speed up performance of internal force calculation is 12 for 16 CPUs and 5.2 speed up performance obtained for contact force calculation at 8 CPUs. Parallel performance results of 256 and 512 CPUs will be provided in the updated vesion of this abstract.

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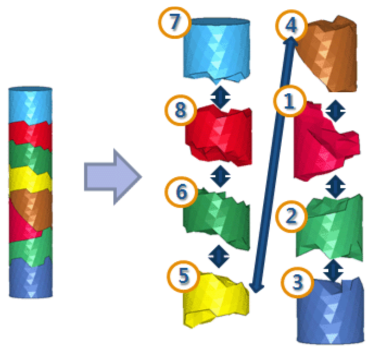

Figure 1: Internal Force Calculation

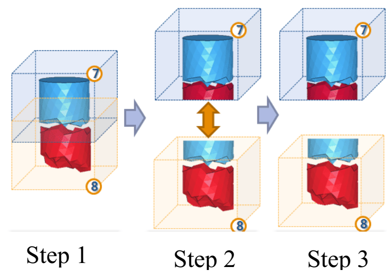

Figure 2: Contact Force Calculation

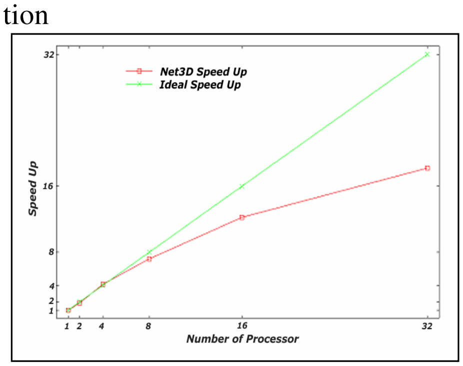

Figure 3: Speed Up Result (Taylor)

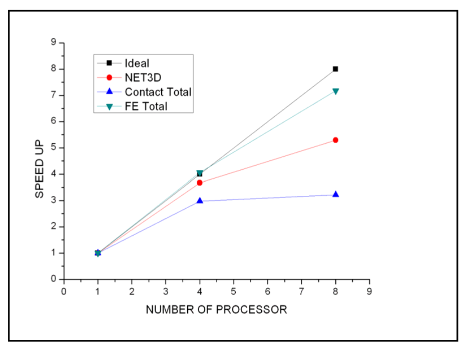

Figure 4: Speed Up Results (Oblique metal Sphere)