A parallel explicit solver for large scale wave propagation problems based on octree meshes

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ABSTRACT

Wave propagation plays an important role in many engineering applications such as structure health monitoring, earthquake analysis, structure-fluid interaction, etc. Numerical methods have been widely employed in the simulation of wave propagation phenomena since analytical solutions are usually difficult to obtain. With the development of high-performance computers, efficient automatic mesh generators and transient solvers are increasingly required to tackle large scale problems with complex geometries.

In this paper, a parallel explicit solver based on the central difference method exploiting the advantages of balanced octree meshes is proposed. Octree algorithms present an automatic approach to mesh generation and are based on a recursive subdivision of the space. To avoid the hanging nodes in octree meshes typically encountered in standard finite element analysis, the scaled boundary finite element method (SBFEM) [1] is deployed as the spatial discretization scheme. In the SBFEM, arbitrarily shaped star-convex polyhedral elements are straightforwardly formulated. Considering the scaling and transformation of octree cells, the stiffness and mass matrices can be pre-computed from a limited number of unique cell patterns. A recently proposed mass lumping technique [2] is extended to 3D yielding well-conditioned diagonal mass matrices. This enables us to leverage the advantages of explicit time-stepping schemes, i.e., it is possible to efficiently compute the nodal displacements without the need for solving a system of linear equations. Furthermore, it is not necessary to assemble the global stiffness matrix as the nodal force vector can be calculated in an element-by-element fashion. A mesh partitioning package is utilized to distributed the work load to multiple processors in a high-performance computer, while minimizing the data communication between these processors.

The performance of our parallel explicit solver is demonstrated by means of several numerical examples, including complex geometries and various practical applications. A significant speedup is observed for these examples with up to one billion of degrees of freedom running on up to 16,384 computing cores.

REFERENCES
