3D Finite Element remeshing with Smooth Particle Hydrodynamics

An application to high speed impacts simulation

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ABSTRACT

Some transient phenomena related to ballistic impacts, high speed impacts or explosions involving very large deformations and perforations can hardly be modeled with the Explicit Finite Element method due to the high distortion of the elements. The Arbitrary Euler Lagrange method [1] may also reach some limits into this domain, because the mesh can hardly be controlled. The SPH "Smooth Particle Hydrodynamic" method [2, 3] better allows to simulate such phenomena because it can handle a much higher deformation level and its time step remains almost constant. These methods are available in RADIOSS [4] which has been used in the industry for simulating high speed impacts or explosions since more than 25 years (RADIOSS® is a registered trademark of Altair Engineering Inc.).

Nevertheless, the SPH method has a higher CPU cost than FE, due to the need of sorting neighboring particles and also because the local approximation involves a much higher number of "nodes" than the Finite Elements.

We are presenting in this paper a method for switching from Lagrangian 3D elements to Smooth Particle Hydrodynamics, in the regions of interest, especially those where the impact occurs or the deformations are higher.

Particles may be substituted to an element based on various criteria: deformation of the element, time step of the element, contact, or physical failure criteria. The particles may have 3 different states: fully active once they are released - let substituted to an element - cloud active while they are interacting with fully active ones, dormant otherwise.
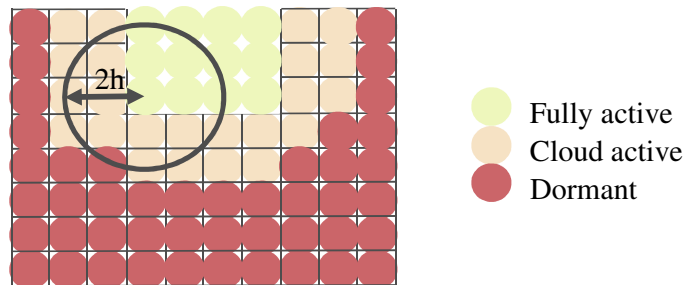
Figure 1: Possible states of particles.

All cloud active particles inherit from the strain-stress state of the finite element they depend on. SPH interaction forces are computed between both fully and cloud active particles. The forces applying to cloud active particles are transmitted to the element they belong to, using the FE shape functions. In turn, the elements are imposing the kinematic of both cloud active and dormant particles.

Substituting particles to an element, the mass, momentum and internal energy are conserved. Some kinetic energy is absorbed, as usual with re-meshing technics. Nevertheless, the different stiffness of Finite Elements and SPH introduce a discontinuity along time, thus a shock wave, when are substituted to an element. A patch test is presented illustrating the effect of this discontinuity, also showing that smoothing velocities [4] may limit the shock wave.

Finally, the method is compared to the pure SPH method with respect to an industrial application of a meteorite impact on a spatial structure. Results and performances are presented.
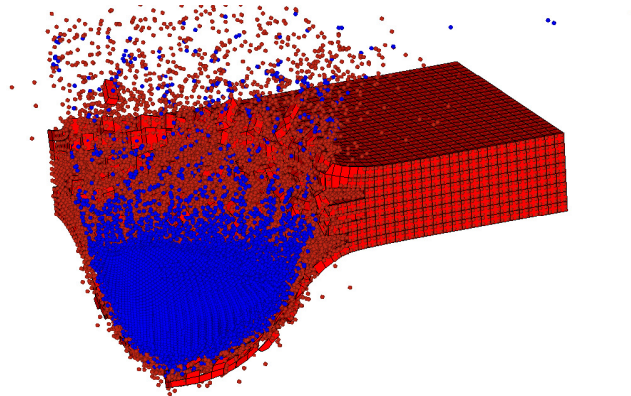
Figure 2: Impact of a debris (SPH only) onto a spatial structure (Remeshing FE into SPH).

The method has demonstrated capabilities of simulating high speed impacts with a reduced computational cost comparing to the SPH method, while being robust with respect to very high deformations.

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