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USING GEOMETRICAL ALGORITHMS TO FACILITATE HAND-OFF BETWEEN SPH AND N-BODY MODELLING OF EJECTA EVOLUTION

John Wimarsson(1), Fabio Ferrari(2), Sabina Raducan(1), and Martin Jutzi(1)
(1) *Space Research & Planetary Sciences, University of Bern, Switzerland*
(2) *Department of Aerospace Science and Technology, Politecnico di Milano, Italy*

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ABSTRACT

The numerical modelling of a kinetic impact into an asteroid can be divided into two stages. The first is characterized by a high-energy event where an impactor collides with a target, leading to cratering, shattering or dispersion of said progenitor. Due to the high energies involved in the impact, it is common practice to use numerical hydrodynamical codes, such as 3D smoothed-particle hydrodynamics (SPH), to accurately model the shock propagation and fragmentation of the target asteroid, which usually occurs within the first few seconds after the collision. The next stage is represented by a lower-energy dynamical evolution of the ejected fragments. For cases where the impact leads to cratering or shattering, the velocity of the ejecta particles will be lower than the escape velocity of the target asteroid, which in turn can lead to the formation of gravitationally bound aggregates of smaller fragments. This regime is modelled using gravitational N-body codes.

In order to transition between the different codes, a hand-off is required. Said operation is not trivial due to two main issues: (i) Since SPH particles do not represent discrete particles, but constituents of a smoothed continuum, they tend to overlap in the physical space. In turn, it is not possible to translate them one-to-one as physical particles in an N-body setting; (ii) SPH simulations require a high resolution, i.e. large number of particles (on the order of ~10^6), to improve realism. However, using that many particles does little to improve the realism of an N-body simulation and simply leads to a large increase in elapsed real time until it is resolved.

In order to facilitate the hand-off, we have developed an interface between SPH and N-body codes that identify clusters of SPH particles after a kinetic impact and groups them together as one single fragment with given physical properties based on its constituents. Each aggregate is created using a friends-of-friends algorithm with a dynamic linking length based on the combined SPH smoothing length of particle pairs. Our approach is unique in that it also assigns a realistic physical shape to the fragment based on the distribution of its SPH particles. This is accomplished using a geometrical algorithm known as α-shape [1]. In turn, the high resolution of the SPH simulation is preserved while removing any overlap between particles and improving performance of the N-body code. The α-shape method has successfully been used in similar studies [2,3]. The main drawback of α-shape when

implemented in interfaces such as ours has been that it needs input based on a characteristic size for individual SPH particles, which makes little sense physically. Said input is referred to as α and sets the resolution of the final 3D shape.

Instead, we use an improved approach where α is computed for each fragment based on the minimum value needed for a set of particles to form a single coherent shape. As a result, our method provides an increase in realism when modelling the dynamic evolution of ejecta after high-energy impacts into asteroids.

References: [1] Edelsbrunner & Mücke, 1994, Transactions of Graphics. [2] Ferrari & Tanga, 2020, Icarus. [3] Ballouz et al., 2019, MNRAS.

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Comments:

(Oral presentation preferred, will attend in person)