

An energy conserving explicit time-integration scheme for Discrete Element Methods with variable time-steps

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Abstract

In the Mka3D code, the authors [1] have been able to simulate the behaviour of a three-dimensional linear elastic material so as to compute the fragmentation of brittle materials like rocks and geomaterials. The discretisation is achieved through rigid convex polyhedral particles. No sphere packing is required to identify material constants because they stem from mechanical constants (i.e. Young's modulus and Poisson's ratio). The forces and torques are computed directly through geometric quantities such as the distance and relative rotation of two particles. This method also allows to have a Poisson's ratio close to 0.5.

In order to properly simulate fragmentation, it is desirable to accurately preserve energy in the numerical time integration in order to prevent artificial over- or under-estimation of the energy to be physically dissipated through deformation and fracture. In addition, stiffening and softening phenomena imply that the time-steps used in the numerical time-integration should vary over a large range, and sometimes abruptly. In the case of variable time-steps, to the best of our knowledge, no explicit scheme has been shown to preserve energy exactly.

We developed a novel explicit time-integration scheme which conserves exactly a discrete energy when applied to a set of pair interacting particles with conservative forces and potentials. This method also allows local time-stepping, which could prove useful to further narrow the computation in regions with stiff stresses and to couple DEM with FEM methods using different time-steps.

The numerical scheme is based on the integration of forces between particles in rigid body motion and the computation of so-called velocity jumps at each time-step.

References

- [1] L. Monasse and C. Mariotti. An energy-preserving discrete element method for elastodynamics. *ESAIM: Mathematical Modelling and Numerical Analysis*, 46:1527–1553, 2012.