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Abstract:

Discrete Element Methods (DEM) naturally conform the discrete microstructure of granular solids when modeling their numerical behaviors. Doing so, special care remains necessary for the shape description of solid particles because of the mechanical influence of such a geometric variable[1]. Leaving aside the spherical idealization, more realistic shapes are usually obtained in DEM adopting rigid aggregates of possibly overlapping spheres or convex polyedra. The formers nevertheless include an inherent unrealistic roundness, while the latters' limitation to convex cases hinders generality. Another DEM shape descriptor has then been recently proposed through the consideration of Level Sets (LS) for the signed distance function to each particle surface[2]. The corresponding LS extension to DEM eventually relies on two ingredients at the particle scale: first, a discrete distance field that can be obtained in a general manner from e.g. computed tomography and which defines inertial properties; second, a surface discretization in terms of boundary nodes that are necessary for contact detection, and that can be obtained from the distance field.

After implementation in the YADE[3] code, the computational implications and versatility of such a LS-based approach are herein presented. A first comparison applies to simple spherical particles, being either LS-described or directly used in classical DEM. It shows memory and time costs increase by two to three orders of magnitude, for a good precision to be achieved[4]. Nevertheless, such computational costs transpose almost directly to more complex, non-spherical shapes. This interesting feature is illustrated on superquadric shapes, also known as superellipsoids. Comparing with another description of superellipsoids seen as convex polyedra[5], the LS approach then appears as promising in terms of computational time for non-spherical shapes.

[1] Cho, G.-C., Dodds, J. and Santamarina, J. C. (2006) Particle shape effects on packing density, stiffness, and strength: natural and crushed sands, *J. of Geotechnical and Geoenvironmental Engineering*, 132(5)
[2] Kawamoto, R., Andò, E., Viggiani, G. and Andrade, J. E. (2016) Level set discrete element method for three-dimensional computations with triaxial case study, *J. of the Mechanics and Physics of Solids*, 91
[3] Šmilauer, V. et al. (2015), Yade Documentation 2nd ed. *The Yade Project* (http://yade-dem.org/doc/)
[4] Duriez, J. and Galusinski, C. (2020) Level Set Representation on Octree for Granular Material with Arbitrary Grain Shape, in D. Šimurda and T. Bodnár (eds) *Proceedings Topical Problems of Fluid Mechanics 2020*
[5] Eliáš ,J. (2014) Simulation of railway ballast using crushable polyhedral particles, *Powder Technology*, 264