DEM capabilities with Polyhedral and Level Set shape descriptors

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Abstract

Geometrically realistic particles are getting more and more available in discrete (DEM) simulations thanks to a variety of dedicated DEM implementations, enabling one to properly address the known influence of particle shape in geomechanics [1]. In addition to the multi-sphere approach, whereby an appropriate number of overlapping spheres are clumped together and act as one rigid body, one can mention the possibility to define a particle's surface as a polyhedra with its set of vertices, edges and facets or through a Level Set description [2]. The latter relies on a discrete field for the signed distance function to the surface at hand, whose zero level set implicitly describes that surface. For the purpose of contact treatment, a surface discretization in terms of boundary nodes is deduced from the distance field and also enters the method as a second ingredient.

Firstly, the capabilities offered by polyhedral particles lead to propose and validate against experimental data a DEM model for Toyoura sand for a wide range of loading conditions (drained and undrained triaxial compression and extension) and various initial void ratios and confining pressures [3]. Polyhedral Discrete Elements are simply but efficiently defined in 3D from a 2D micrograph of Toyoura sand (Fig. 1). In addition to show satisfactory predictive abilities, the model, through a parametric analysis, illustrates once more the importance for a proper calibration in DEM of initial fabric, in addition to shape or contact parameters.

Second, the polyhedral approach is compared with the Level Set one, in the case of implementations into the YADE open-source code [4,5,6]. While being orders of magnitude heavier than for classical spheres [7], Level Set (LS) computational costs are shown to be possibly lighter than those of polyhedra and may be further optimized be it in terms of memory or time cost. LS-based simulations finally address the mechanical behaviour of superquadric particles (superellipsoids, Fig. 2).

References

[1] G.-C. Cho, J. Dodds and J. C. Santamarina, Particle shape effects on packing density, stiffness, and strength: natural and crushed sands, *J. of Geotechnical and Geoenvironmental Engineering*, 132(5), 2006

[2] R. Kawamoto, E. Andò, G. Viggiani, and J. E. Andrade, Level set discrete element method for three-dimensional computations with triaxial case study. *J. of the Mechanics and Physics of Solids*, 91, 2016

[3] T. Mohamed, J. Duriez, G. Veylon and L. Peyras, DEM models using direct and indirect shape descriptions for Toyoura sand along monotonous loading paths, *Computers and Geotechnics*, 142, 2022

[4] V. Šmilauer et al., Yade Documentation 3rd ed. *The Yade Project* (http://yade-dem.org/doc/)

[5] J. Eliáš, Simulation of railway ballast using crushable polyhedral particles, *Powder Technology*, 264, 2014

[6] J. Duriez and C. Galusinski, A Level Set-Discrete Element Method in YADE for numerical, micro-scale, geomechanics with refined grain shapes, *Computers & Geosciences*, 157, 2021

[7] J. Duriez and S. Bonelli, Precision and computational costs of Level Set-Discrete Element Method (LS-DEM) with respect to DEM, *Comp. & Geotechnics*, 134, 2021

[8] B. Li, Effect of fabric anisotropy on the dynamic mechanical behavior of granular materials. *Ph.D. thesis, Case Western Reserve University*, 2011

Figures

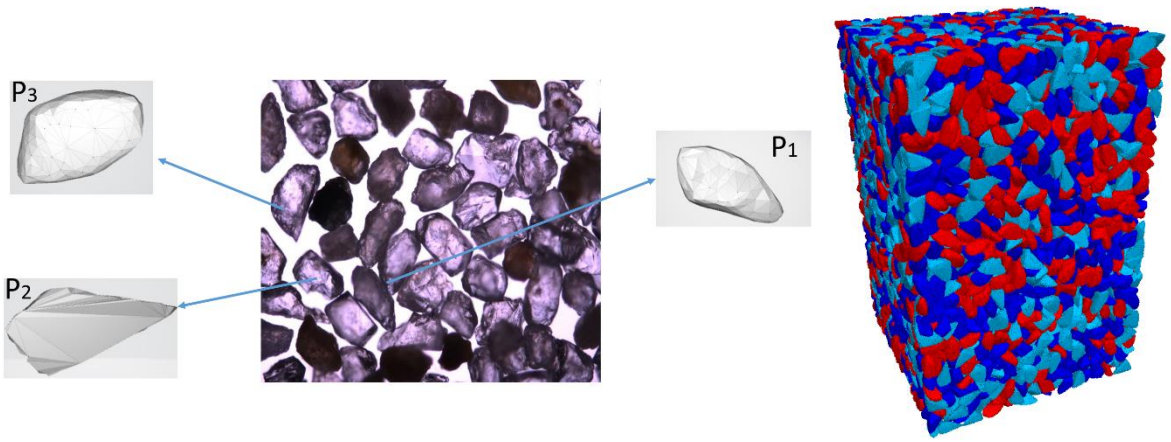

Figure 1: *Polyhedral model for Toyoura sand [3] Left: micrograph [8] with corresponding Discrete Elements. Right: corresponding numerical packing*

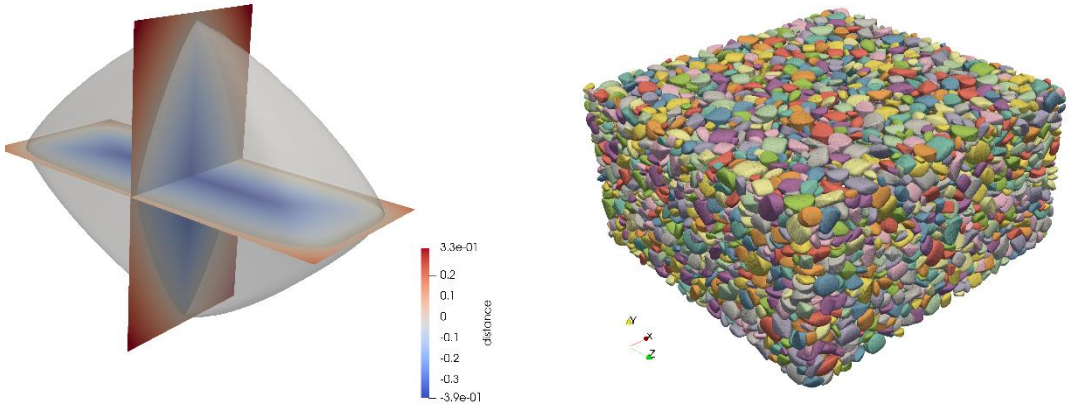

Figure 2: *Level Set description of superellipsoids*