Capabilities of Level Set and Polyhedral shape descriptions for superellipsoids and Toyoura sand

Jérôme Duriez, Tarek Mohamed, Cedric Galusinski

HAL Id: hal-04222029

https://hal.inrae.fr/hal-04222029v1

Submitted on 28 Sep 2023

Capabilities of Level Set and Polyhedral shape descriptions for superellipsoids and Toyoura sand

Jérôme Duriez, INRAE, Aix Marseille Univ, RECOVER
Aix-en-Provence, France – jerome.duriez@inrae.fr

Tarek Mohamed, INRAE, Aix Marseille Univ, RECOVER
Cédric Galusinski, IMATH, Université de Toulon

I agree to publish the presentation after the workshop as a file at the ALERT webpage: ■ **yes** ☐ **no**

Keywords: Level Set-Discrete Element Method (LS-DEM) ; Polyhedra ; particle's shape

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 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 and facets, e.g. [2], or through a Level Set description [3,4]. 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. 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 [5]. While being orders of magnitude heavier than for classical spheres [6], Level Set (LS) computational costs are shown to be possibly lighter than those of polyhedra. 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] J. Eliáš, Simulation of railway ballast using crushable polyhedral particles, *Powder Technology*, 264, 2014
[3] 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
[4] R. Kawamoto, E. Andò, G. Viggiani and J. E. Andrade, All you need is shape: Predicting shear banding in sand with LS-DEM, *J. of the Mechanics and Physics of Solids*, 111, 2018
[5] V. Šmilauer et al., Yade Documentation 2nd ed, 2015, http://yade-dem.org
[6] 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
[7] B. Li, Effect of fabric anisotropy on the dynamic mechanical behavior of granular materials. Ph.D. thesis, Case Western Reserve University, 2011

- Selected presentations can be submitted for a special issue of the *European Journal of Civil and Environmental Engineering*.
- The number of the workshop oral presentations is limited. Presentations can be also accepted as a poster and published after the workshop at the ALERT webpage.
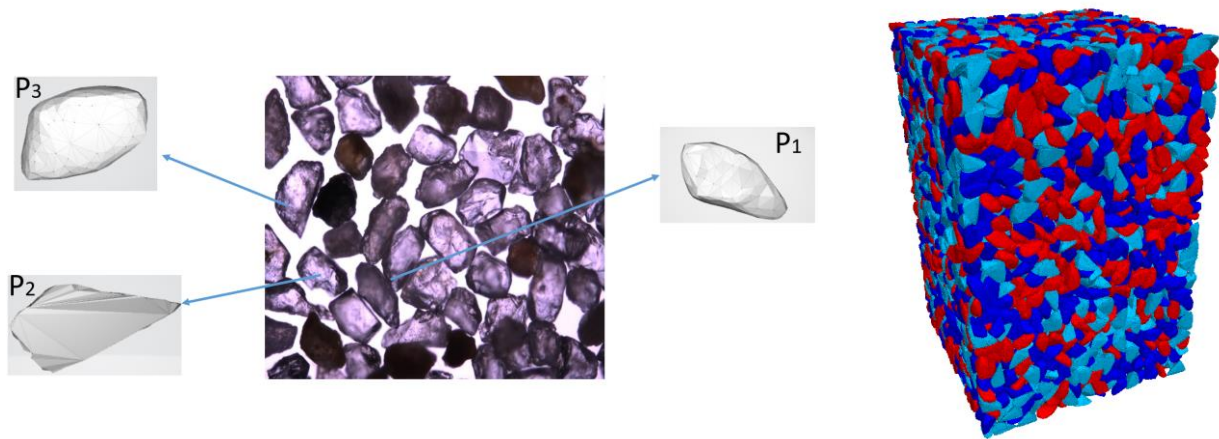
Figures

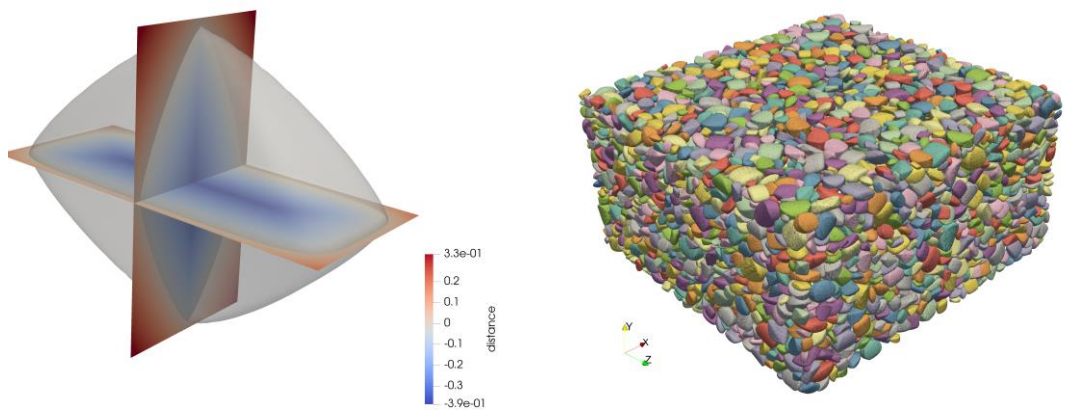Fig. 1: Toyoura sand polyhedral description. Left: micrograph [7] with corresponding Discrete Elements. Right: corresponding numerical packing

Fig. 2: Level Set description of superellipsoids