ECCOMAS Thematic Conference on Multibody Dynamics
June 29 - July 2, 2015, Barcelona, Catalonia, Spain

A parametric approach to the generation of multidisperse granular flows for particle simulations

Alessandro Tasora*, **Ida Critelli#**, **Hammad Mazhar▽**

* Department of Industrial Engineering
Università degli Studi di Parma
Parco Area delle Scienze 181/A, 43100, Parma, Italy
tasora@ied.unipr.it

Department of Mechanical Engineering
Politecnico di Milano
Via La Masa 1, 20156, Milan, Italy
ida.critelli@polimi.it

▽Department of Mechanical Engineering
University of Wisconsin
Madison 2035ME, 1513 University Avenue Madison,WI 53706-1572
hmazhar@wisc.edu

Abstract

This paper presents a novel approach to the generation of particle flows.
Usual methods for the initialization of granular material in multi-body simulations are based on the generation of particles in random positions, where the size of the particles follows a statistical distribution given by a single granulometric curve. Although this is sufficient in various applications, there are cases where other properties of the particles should be subject to randomization, for example friction coefficients.
To this end we developed a novel systematic approach where particles can be sorted from a probability space that involves also other parameters such as density, aspect ratio, geometric properties, and so on. The method is fully parametric, in the sense that most properties of the generated particles can be assigned to statistical distributions, using a modular implementation in our simulation software. Probability distributions are introduced as C++ objects; we implemented a library of distributions of various types, either as probability density functions or cumulative distribution functions. The random variates are generated using the Smirnov theorem on inverse transform sampling.
Shapes of the particles can belong to different classes, for instance convex hulls, spheres, beams, and so on; those classes are unlimited since they can be extended by means of object oriented programming, and each class introduces statistical distributions about its geometric parameters. Each shape generator can be assigned to a particle family; those families are sorted according to a discrete statistical distribution. Particle families can be organized in hierarchical trees of sub-families, hence obtaining a high level of configuration of the system.
The way that particle families, generators and statistical distributions are assembled can be defined by an optional configuration file that leverages the JSON serialization format; we refer to this information as the *DNA* of the granular flow. This opens the road to parametric studies where such granular flow *DNA*

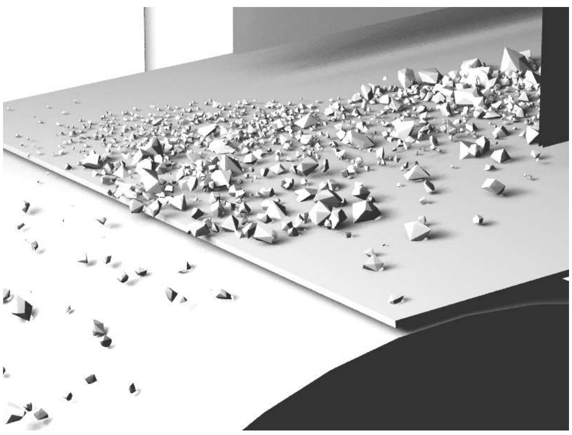

Figure 1: Multidisperse granular flow from a single shape class.

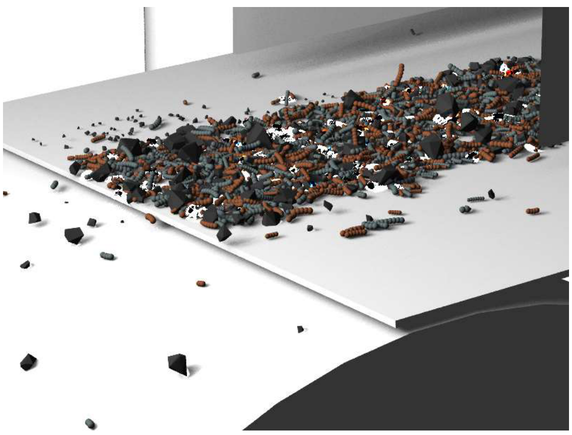

Figure 2: Multidisperse granular flow from multiple shape classes.

is automatically changed during multiple simulation runs, for instance in optimization or in sensitivity analysis.
Figure 1 shows an example of a random generation of particles in a multidisperse granular flow from a single particle class, namely convex hulls that represent fragments in a shredding process. Here shape parameters follow statistical distributions about size, aspect ratio and amount of detail, to name a few. As shown in Figure 2, multiple families with particles of different classes can be mixed in a stochastic way, according to a provided discrete statistical distribution.
We tested this framework within our multibody simulation software whose formulation, based on Differential Variational Inclusions (DVI), can target problems with a massive number of particles with frictional contacts [1]. To this end we performed benchmarks with hundreds of thousands of particles on a parallel computing architecture [2]; in order to improve the efficiency of the collision detection algorithm we designed an innovative optimization strategy where the probability space is discretized by pre-sampling it with a limited number of particle that we call particle prototypes, so that all following particles are just clones of these prototypes. This saves memory because geometric details of clones can be referenced by sharing a single data structure.
This approach to the generation of multidisperse granular flow originated from our researches on separation processes used in recycling plants of electronic waste [3], where particles have stochastic properties of geometry, density, electric charge and material type; then we extended this concept to other applications that benefit from this parametric framework, for instance in simulations of earth-moving machines interacting with granular soil.

References

[1] M. Anitescu and A. Tasora. An iterative approach for cone complementarity problems for non-smooth dynamics. Computational Optimization and Applications, Vol. 47, No. 2, pp. 207–235, 2010.

[2] D. Negrut, A. Tasora, H. Mazhar, T. Heyn, P. Hahn. Leveraging Parallel Computing in Multibody Dynamics. Multibody System Dynamics, Vol. 27, pp. 95–117, 2012.

[3] I. Critelli, A. Tasora, A. Degiorgi, M. Colledani. Particle Simulation of Granular Flows in Electrostatic Separation Processes In SIMUL 2014 Sixth International Conference on Advances in System Simulation, 2014.