MODELING SNOW AVALANCHES WITH MWDiEM

Katalin A. Gillemot[1*], and David Visontai[2]

[1] *ENGAGE - Geomorphological Systems and Risk Research, Department of Geography and Regional Research, University of Vienna, Vienna, Austria*
[2] *Department of Materials Physics, Eötvös Loránd University, Budapest, Hungary*

ABSTRACT: MWDiEM is a new open-source, discrete element model based numerical tool, that is able to effectively model the dynamics of polyhedral and spherical granular particles. The tool is especially aimed at geological mass-waste applications where the fluid content of the flow is none or negligible, e.g. rock avalanches, boulder falls, dry sand, gravel and debris slides, dry debris flows and snow avalanches. The model is prepared for GIS implementation; includes possible entrainment and erosion of the particles; the use of different basal topographies and obstacles in the path of the movement is implemented and different slide initiation/slope failure methods are realized, like vibrations or forced breakup of a block of mass. The simulations give us the opportunity to look inside the dynamics of avalanches, including flow velocities, shear rates, segregation patterns and to explain any unexpected run-out zone geometries, providing a useful tool in the future for both scientist and avalanche professionals.

KEYWORDS: snow avalanche dynamics, discrete element method, granular particles, runout zone, segregation, numerical simulation

1. INTRODUCTION

One very important tool in today's natural hazard research are numerical models. The rapid development of computational power in the 21st century has lead to these tools being used for both prediction, risk assessment and to get a better understanding on the underlying physical phenomena.
The dynamics of avalanches is usually simulated with different kinds of continuum models, as the computational cost of these is usually reasonable even when modeling large scale real life events. However including a solid phase into these simulastions is usually not possible or only with great limitations.
These models usually approximate the whole avalanche as in the fluid phase, not accounting for phenomena stemming from the behavior of a large number of discrete solid particles included in the flow. Such an example is size-segregation, where smaller sized particles sink to the bottom of the flow, lubricating it, thus resulting in a longer runout distance then expected. Another example is when different shaped particles lock together, forming larger chunks or blocks, once more changing the dynamics of the flow. In order to model the solid phase we have developed a discrete element model (DiEM) based numerical environment (called: MWDiEM), that is able to effectively model the dynamics of polyhedral or spherical granular particles. These shapes are anticipated to realistically model a number of particle types found in real avalanche events (e.g. chunks of a slab or rounded snow grains). In DiEM the trajectory of each particle is followed individually, resulting in an extended insight into

** Corresponding author address:*
Katalin A. Gillemot, ENGAGE - Geomorphological Systems and Risk Research, Department of Geography and Regional Research, University of Vienna, NIG 5th Floor, Universitätsstrasse 7, A-1010 Vienna, Austria
email: katalin.gillemot@univie.ac.at

the physical properties of the flow, as we have constant knowledge of particle positions, particle orientations, velocities, forces, and a number of other interesting physical parameters at each step in time.

2. MWDiEM

MWDiEM (also called MAWAMOSCA) is a Python based DiEM code, that uses a soft-sphere approach, handles both spherical and convex polyhedra shaped particles and accounts for friction between the grains. Contact detection is based on a modified GJK algorithm [Gilbert et al., 1988] and is heavily parallelized over the GPU. The code is optimized to be used on High End Computing (HEC) facilities, however it is designed in a way, that for smaller systems it can also run on personal PCs or smaller grids.

The particle shapes possible range from tetrahedrons to arbitrary polyhedra and the option of adding spheres into the system is also given. Possible fracture of the particles is also implemented. In that case breaking threshold is set by the exact position of the particles within the system in order to account for the regions with different shear rates or by using user set specific force criteria on each particle independently. From simply halving the particles, to it losing a small chunk or even pulverizing in one single instance is possible.

A number of further development points are currently being added to MWDiEM to be able to model real-life mass-waste events: (1) Geographic Information Systems (GIS) support. (2) The use of different basal topographies. Bases made of particles “glued together” (meaning constraints between sets of particles), or bases consisting of a large number of triangulated planes to be possible, both allowing for basal entrainment as well. (3) Obstacles may be included in the path of the movement (e.g. a dam or columns) with the same method as in the previous point. (4) Different slide initiation/slope failure methods are implemented, like vibrations or forced breakup of a block of mass. (5) It will be possible to use data acquired from the continuum model r.avaflow [Mergili et al., 2014-2018] as an initial condition. (6) The basic inter-particle force law used is the Hertz-Mindlin contact theory [Hertz, 1896], however other contact theories (e.g. with cohesion or for very high speed collisions found in falls or very rapid, almost gaseous flows) are applicable.

In the current phase we are working on validating MWDiEM against a number of past real-life events, -including snow avalanches-, examples that can be relatively well approximated by dry granular avalanches. Making a comparison is not always an easy task as the information available from field measurements is usually very limited (e.g. only the observed release and deposition areas, the entire impact area and release and deposition heights are known). However if these geometrical parameters show a good match on a certain type of basal topography one can expect the model to be valid. The knowledge obtained during this phase of the research equips us with a first hand experience on (1) what MWDiEM is capable of, (2) under what conditions or limitations and on what scales does it work the best and (3) in which cases: can the two models, r.avaflow and MWDiEM work side by side bridging a gap between the continuum and discrete modelling principles.

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