MELODY: A Multibody Meshfree Simulation Code for Numerical Tribology and Geomechanics

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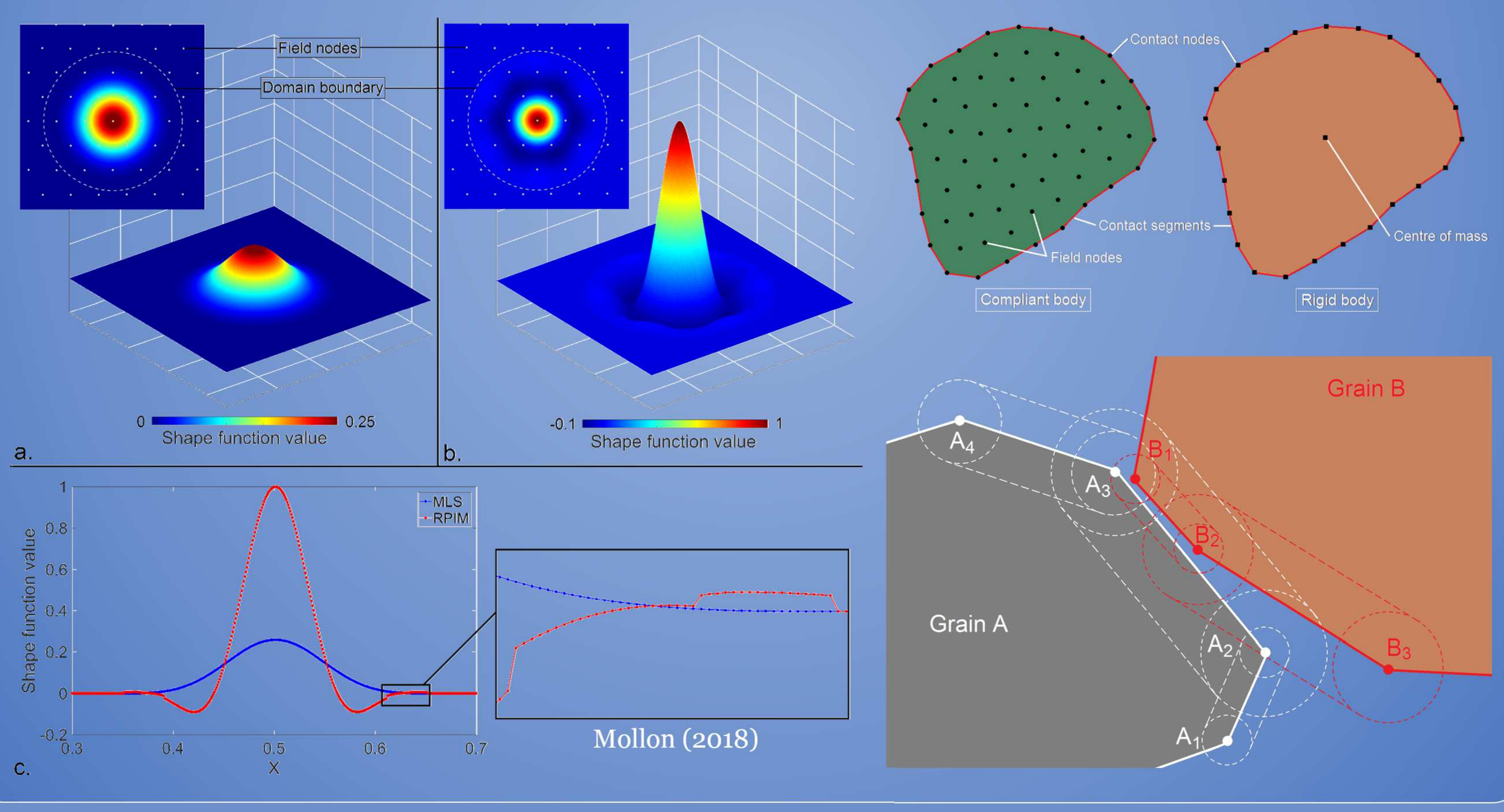
MELODY (Multibody Element-free Open code for Dynamic simulations) is an open-source code dedicated to numerical tribology and geomechanics. It combines discrete and continuum mechanics in a single framework.

Two kinds of bodies may be introduced in MELODY : deformable and rigid bodies. While the latter obey to Newtonian dynamics, the former do rely on a meshfree discretization (using Moving Least Squares shape functions) in order to simulate large strains in a stable manner.

Bodies may have arbitrary shapes, and contacts are solved using a penalized two-pass node-to-segment approach, which takes advantage of optimized proximity and contact detections. The semi-discrete equations are dynamically integrated in time using an adaptive explicit solver.

The code is written in C++ and parallelized in OpenMP.



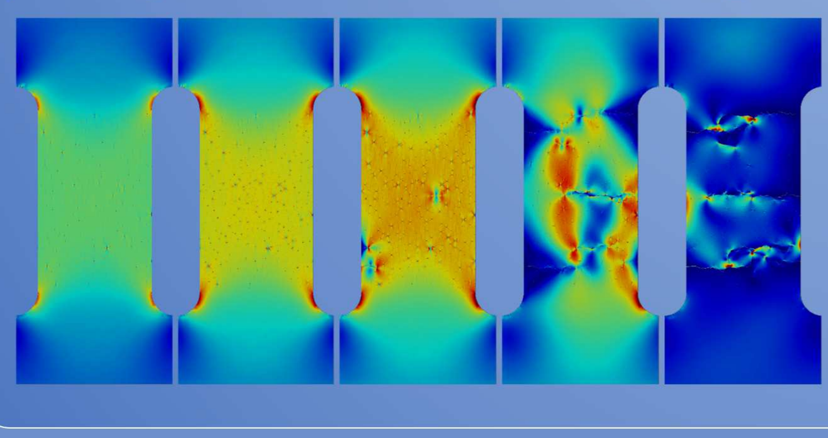
MELODY is primarily applied to tribological simulations. A typical situation is the wear of rock cutting tools. In such tools, the rock-cutting is performed by micro-diamonds embedded in a sintered metallic matrix. However, this matrix gets worn by the continuous flow of rock debris created by the diamond, and this wear ultimately leads to diamond failure.

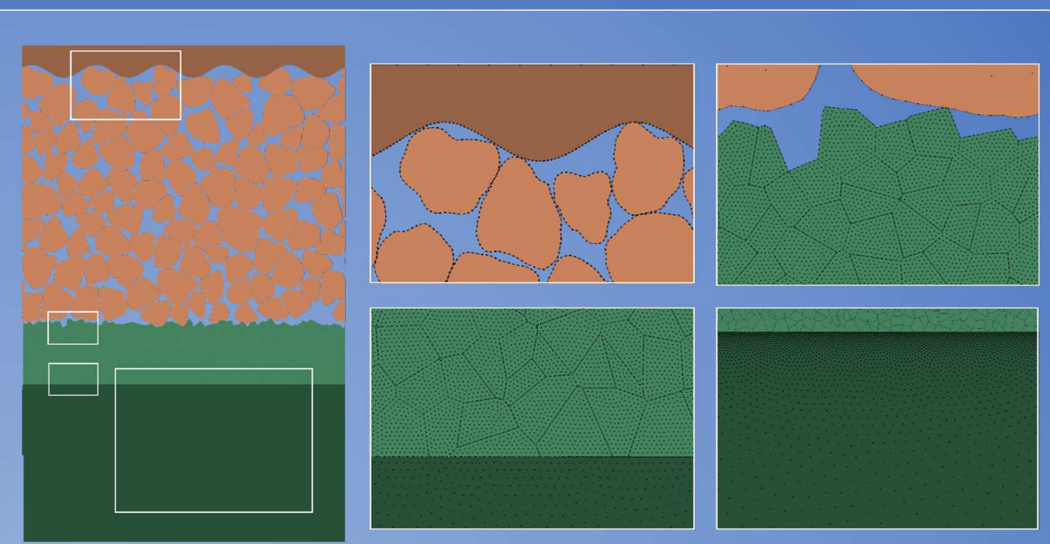
To simulate this situation, we consider :

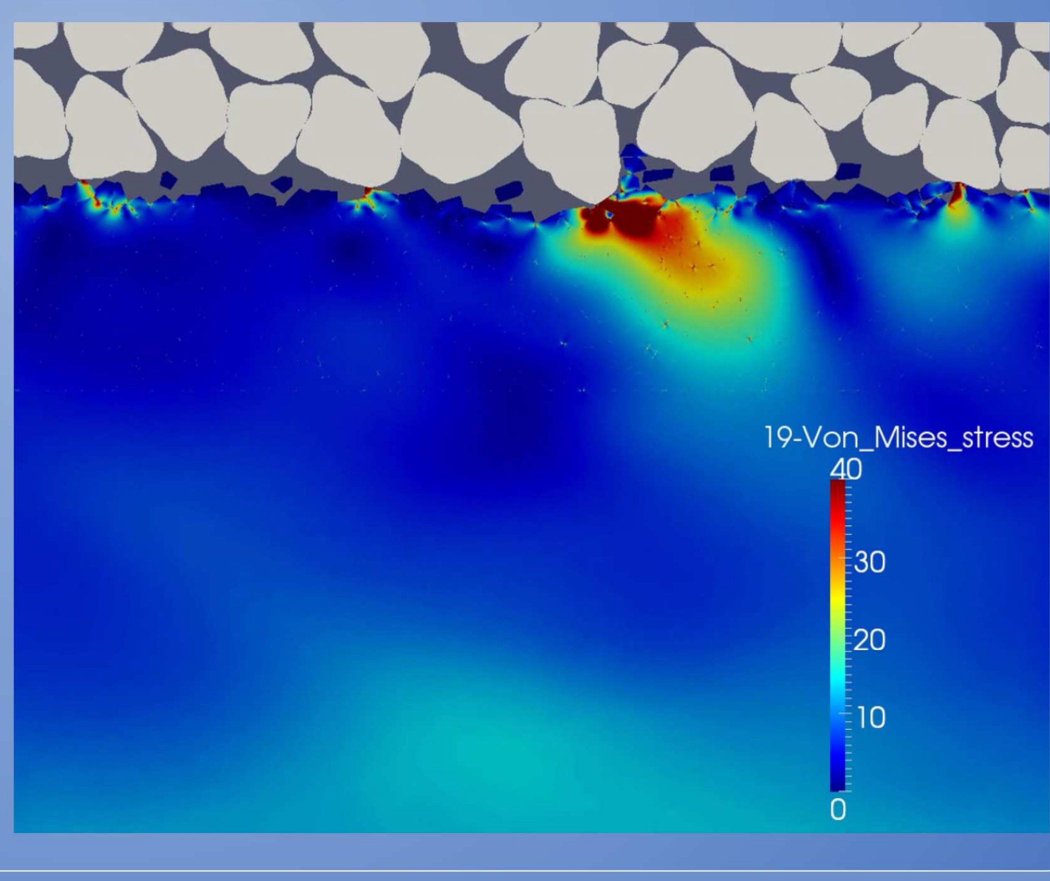
-rigid grains with angular shapes for the rock debris, and a rigid substrate transmitting the load and the cutting velocity.

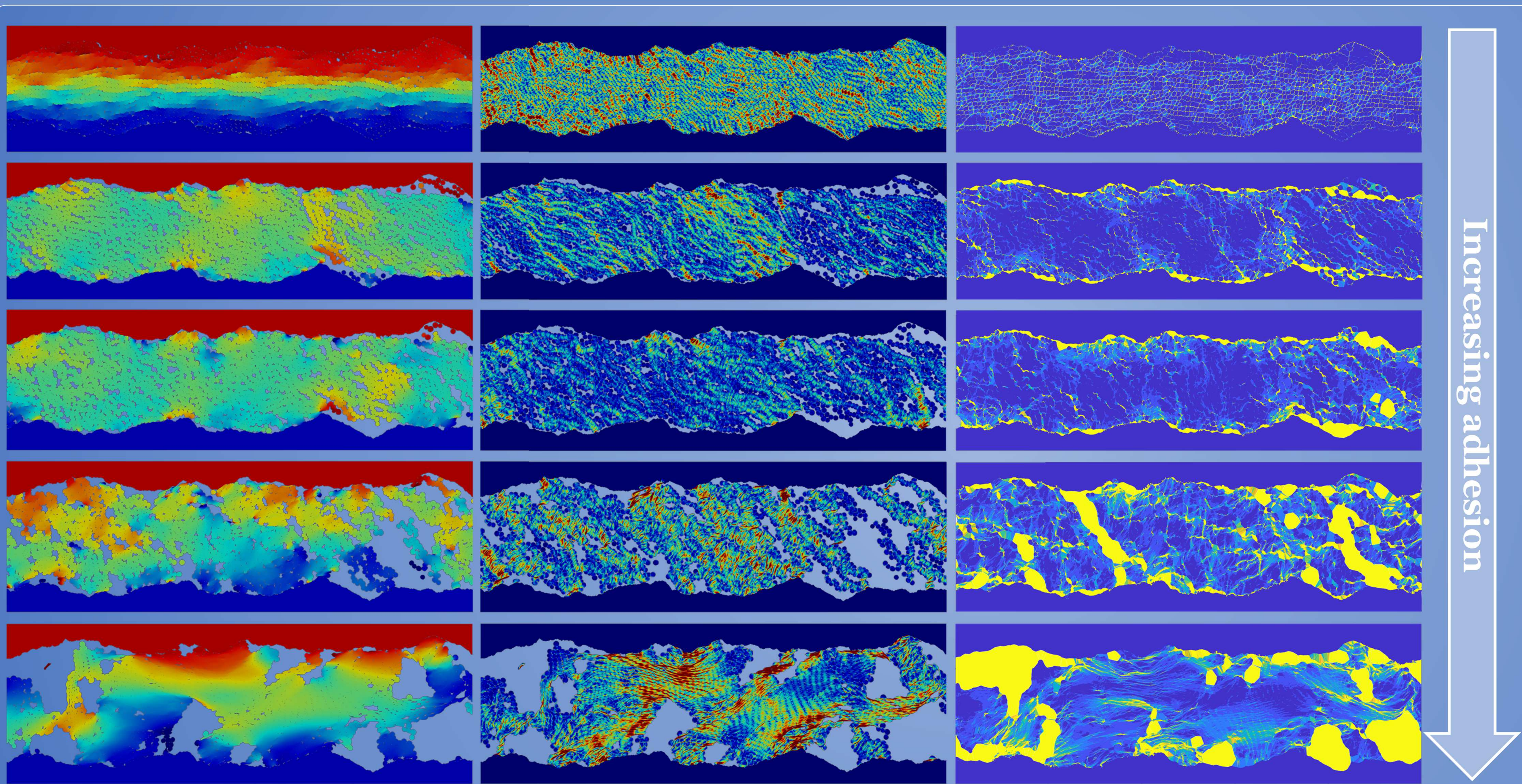
-deformable grains with polygonal conformal shapes for the metallic matrix, linked by bonds that get damaged based on a fatigue law.

This simulation makes it possible to simulate dynamically the stress field in the abraded metallic matrix, the progressive damage of the microstructure, and the release of wear material, providing in turn the wear rate of the cutting tool.









Horizontal Velocity | Von Mises Stress | Local Strain Rate

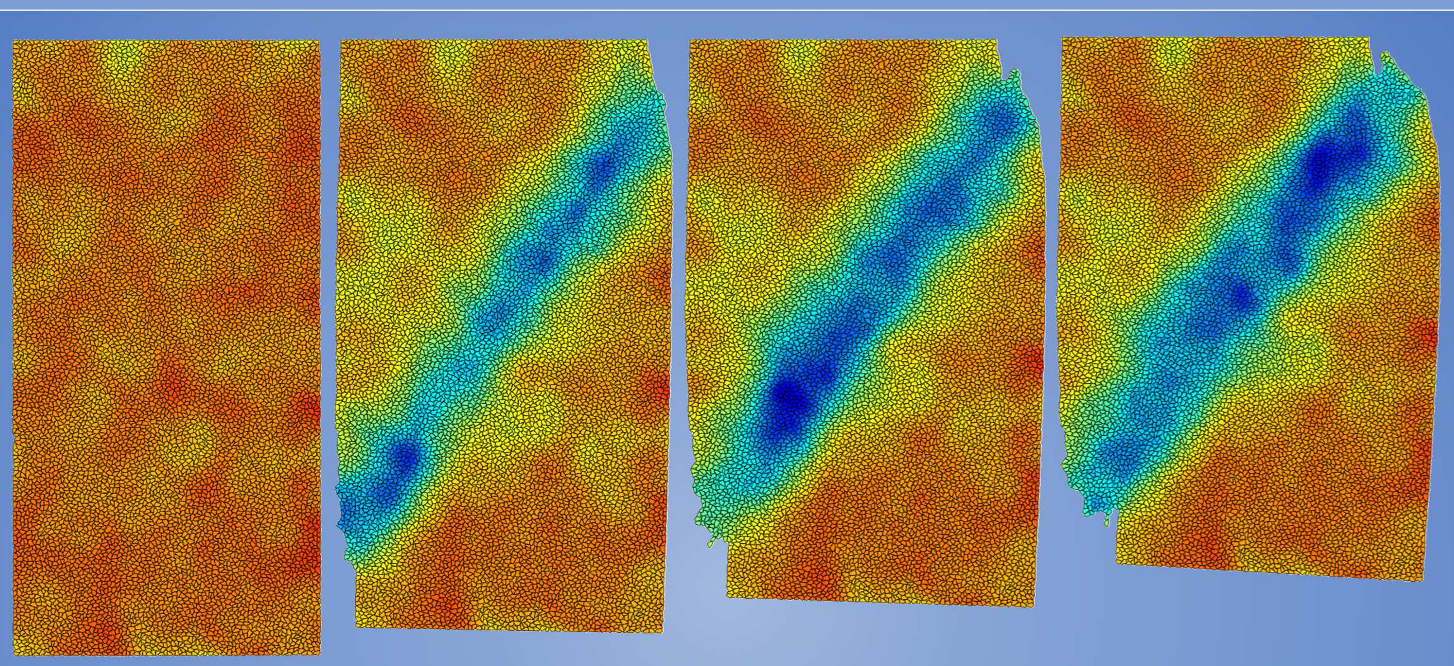
The mechanisms of friction and wear in mechanical contacts are complex because, in any real contact, the two contacting bodies get separated by a so-called Third Body, which is created by the degradation of the surfaces and which transmits the load while accommodating the velocity gradient.

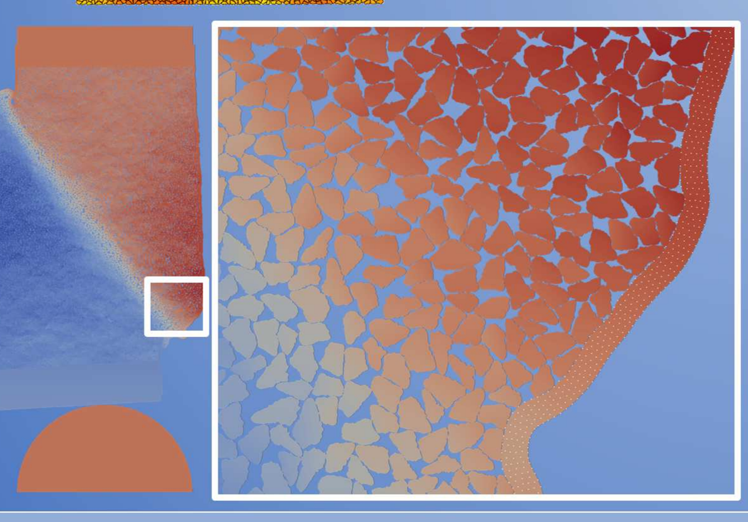
Experimental studies have shown that the way this third body flows controls both friction and wear. However, a relevant simulation of such a flow is challenging with conventional numerical methods.

In this study, two rough and rigid surfaces were put into relative motion under a normal load, in the presence of a large collection of highly deformable hyperelastic grains. These grains are used in order to simulate the discontinuous and yet plastic behavior of the third body.

Among the numerous parameters that can be tuned to address a specific third body, one of the most interesting is the adhesion force between the grains. By progressively increasing this quantity, several flow regimes emerge: quasi-liquid plastic flow, localized shear, plug flow with wall-slip, brittle cracking, ductile agglomeration, and rolling.

For each of these regimes (and several more), MELODY provides typical stress patterns, local accommodation phenomena, friction coefficients, loading history on the surfaces, etc.

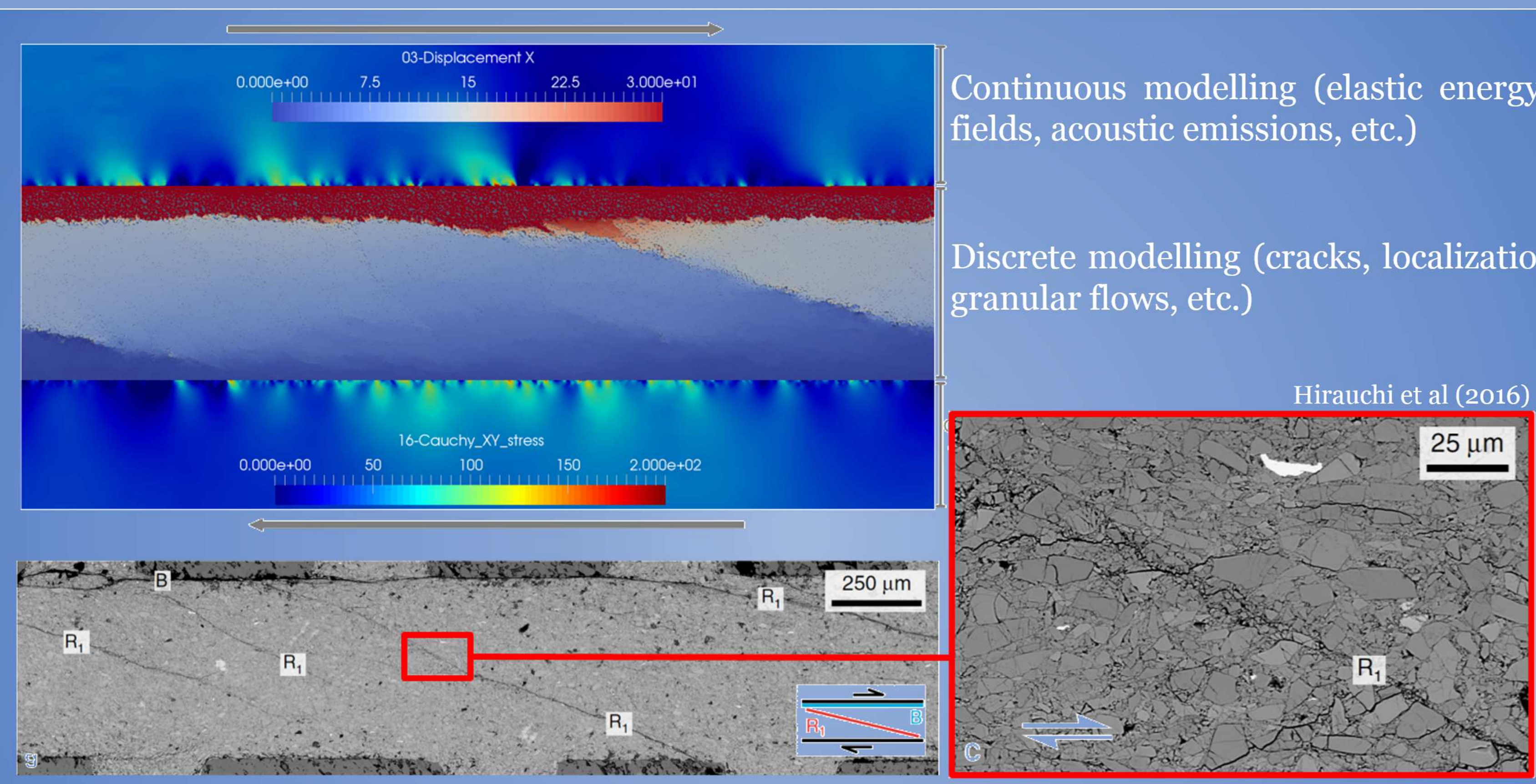




In addition to tribology, MELODY finds many applications in granular science and geomechanics.

By mimicking realistic loading conditions (including a fluid pressure transmitted by a highly deformable rubber membrane), it can reproduce typical dilation/localization patterns in biaxial tests performed experimentally on sands.

Since the shapes of the grains are arbitrary, they can be chosen in order to match those of a given sand and make quantitative outputs more reliable.



Continuous modelling (elastic energy, stress fields, acoustic emissions, etc.)

Discrete modelling (cracks, localization, granular flows, etc.)

The ability of MELODY to deal with rigid and continuous bodies in a common framework makes it a good candidate for the simulation of faulting and earthquake mechanics, where a layer of granular gouge typically separates two loaded and elastically-deformed mediums.

Preliminary studies show that simulations of the shearing of a granular gouge made of rigid polygonal grains reproduce very well the experimental patterns (Riedel shear bands, wall slip, etc.). It might allow to shade light on some micromechanical justifications of the widely-used but still empirical rate-and-state friction laws.

The open-source code MELODY has been applied to a wide variety of situations in the framework of numerical tribology and geomechanics. By combining rigid and deformable bodies, it makes it possible to analyze the complex dynamic interactions between (i) the ability of deformable bodies to change their shape and to store elastic energy, and (ii) the rich phenomenology of dissipative granular and divided materials. It can also reveal the quite unexplored behavior of soft adhesive granular materials, which appear to have a wide variety of flow regimes. Future developments will be dedicated to the enrichment of the local physics implemented in the code, including grain breakage, heat production and conduction, and fluid coupling. A 3D extension of this currently 2D code is also foreseen, as well as specific strategies to address multi-scale issues.

The current version of the code (sources, executable, and matlab preprocessor) can be downloaded on *http://guilhem.mollon.free.fr*.

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