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To cite this version:

Vincent Visseq, Alexandre Martin, David Dureisseix, Pierre Alart. Issues in domain decomposition method dedicated to non-smooth contact dynamics. Euromech 514: New trends in Contact Mechanics, Mar 2012, Cargèse, France. hal-00776135

HAL Id: hal-00776135

https://hal.science/hal-00776135v1

Submitted on 15 Jan 2013

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Issues in domain decomposition method dedicated to non-smooth contact dynamics

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Summary: A FETI-like Domain decomposition dedicated to Contact Dynamics is considered here, especially concerning "corner grain" treatment and its influence on the numerical simulation. Moreover, parallel implementation of Non-Smooth Contact Domain Decomposition (NSCDD) using MPI library is studied as regards of load balancing and computing performances, leading to motivate time homogenization techniques.

Introduction

Simulations of large granular systems, such as a railway ballast submitted to cyclic loading or the behavior of the Nîmes arena and Arles aqueduct subjected to seismic loading, are still computational challenges. Non-Smooth Contact Dynamics [1], or contact dynamics in short, allows to efficiently handle two main characteristics of such assemblies which are discreteness and non-smoothness. To overcome numerical limits, parallelization of algorithms has first being performed by introducing non-intrusive commands in iterative solvers such as non linear Gauss-Seidel (NLGS) and conjugate gradient [2].

From a few years, the next step in this way is under development implying domain decomposition suited to non-smooth dynamics. Two partitioning strategies may be considered [3]: the primal approach, consisting in distributing contacts, leads to a simple algebraic partition of the equations, and the dual strategy (NSCDD), which implies to duplicate interface grains by introducing a linear global gluing step in addition to generic steps of the considered algorithm. Theoretical and numerical studies are presented related to this NSCDD approach.

Interface topic

Non trivial sub-structuring topology may lead to introduce edge or corner grains, i.e. grains formally split in more than two parts. Links are then stated as gluing conditions between these parts (see Fig. 1) and sufficient gluing conditions should be stated for each interface grains to ensure to recover the reference problem solution. Contrary to the continuous media case where face, edge and corner nodes can be distinguished in 3D, the discrete systems studied herein do not differentiate edge and corner topology.

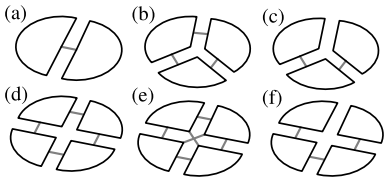

Figure 1: Some examples of gluing conditions between interface grains in 2D.

Depending on the chosen links, the interface operator turns out to be non-invertible and would have to be solved by iterative algorithms or specific direct solvers. Nevertheless we introduce a way to obtain invertible sub-matrix related to corner grains both for 2D and 3D problems.

Numerical results

To test the robustness of the NSCDD approach with respect to various "well-known" aspects of the mechanical behavior of granular media [4], a realistic biaxial test is performed from various sub-structuring topologies, including those possibly leading to corner grains (see Fig. 2).

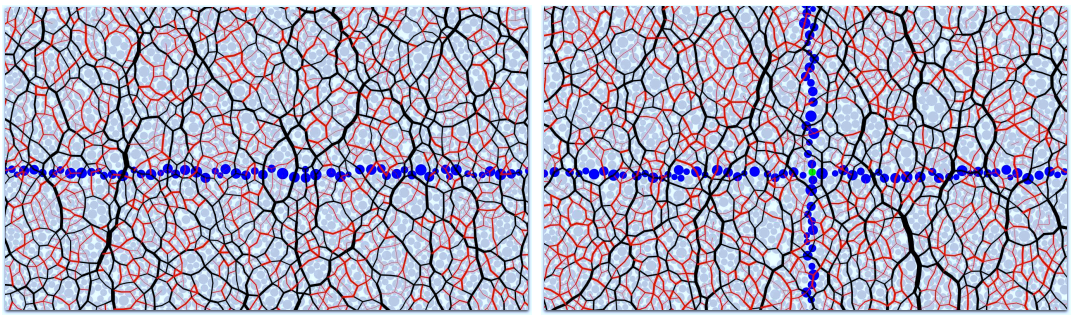

Figure 2: Maps of force chains in a portion of sample under biaxial loading. The multiplicity is: 1 for a gray particle, 2 for a blue particle and 3 for a green particle.

The simulations for different sub-domains give the same global behavior. However, slight fluctuations appear for large strains, exemplifying the multiplicity of solutions which characterize simulations of granular systems. Indeed, at large strain of the biaxial test, dilation is localized within shear bands appearing and vanishing throughout the system underlying the saturation of the solid fraction. The shear bands are slightly different from one partitioning to an other even if, on the average, the solid fraction is identical. In fact, localization phenomena leads to multiple possible physical solutions, and it has been already exemplified that the formation of the shear band depends on the details of the numerical parameter of the simulations (time step, solver, number of iterations...) [2].

Load balancing of sub-domains and performances

The present approach has been implemented in the LMGC90 platform [5]. For parallel implementation using libraries such as MPI and OpenMP, load balancing is an other complex topic. Many parameters may be taken into account such as: the number of bodies and of contacts included in sub-domains, and the characteristics of the medium considered (inertia parameter, interactions law...).

Finally, simulations performed up to large cumulative strains clearly leads to motivate time homogenization techniques in order to improve performances.

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