Chapter 5
The Contact Dynamics Method

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ABSTRACT

The Contact Dynamics method, developed still in the 1980s, was originally applied for granular assemblies because of its efficiency in simulating rapid granular flows or vibration problems of discrete systems. In the oldest models the elements were spherical and perfectly rigid, but later the application of polyhedral and deformable elements also became widespread, allowing for the reliable simulation of problems related to masonry structures. The basic unit of the analysis in Contact Dynamics is the pair of two randomly chosen elements. The essence of the method is to find the contact force vector between the two elements in such a way that during the analysed time step the elements should not overlap each other. At the considered time instant an iterative process sweeps along randomly chosen pairs over and over again, and gradually adjusts the estimated contact forces to get an improving approximation of a state that satisfies the dynamic equations of the system. The method is particularly advantageous for earthquake analysis of masonry structures.

INTRODUCTION

The NSCD (Non-Smooth Contact Dynamics) method was presented to the public at the end of the 1980ies by M. Jean and J.J. Moreau (Moreau, 1988; Jean & Moreau, 1992). Its first main field of application was granular mechanics: in comparison to previous discrete element techniques, the NSCD method turned out to be particularly fast and efficient when simulating granular flows, rapid avalanches, segregation, vibration problems of granular materials etc. Since the individual deformations of the grains are usually negligible in these problems, models consisting of perfectly rigid elements were mostly applied at that time. In the first versions the elements were mostly spherical, but later the application of polyhedral elements also became widespread. Contact Dynamics models brought significant scientific achievements in the field of the dynamics of granular materials. (While the original papers on NSCD were rather abstract and not very helpful in providing practice-oriented explanations how the method really worked, the paper of Unger and Kertész (2003) brought a leap forward: it gave a clear, detailed, code-writer-oriented introduction to the line of thought of the method, providing valuable help for those

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who wanted to write their own code and also for those who just wanted to understand the main concept lying behind the software which they were applying in their researches.)

For masonry structures polygonal or polyhedral elements are obviously more suitable than spheres, and the deformability of the elements is often also important to take into consideration. Jean and Moreau (1992) and Jean (1999) introduced the basics of modelling masonry walls with deformable rectangular blocks in NSCD, and Jean developed the software called LMGC that gave realistic results for the quasi-static selfweight problem of a planar wall (Jean, 1999). Dubois extended the method, developed the open code LMGC90 (Dubois & Jean, 2006), and offered it to the research community not only for using it but also for further developments. LMGC90 can model rigid or deformable, 2D or 3D bodies of spherical or polyhedral shape. Since its release in the early 2000ies several scientists and engineers have applied it for different quasi-static or dynamic problems related to masonry mechanics.

Another available Contact Dynamics software is SOLFEC (Koziara & Bićanić, 2008). SOLFEC aimed at providing a user friendly platform for testing formulations and solution methods. The code implements different (rigid, uniform-strain and finite element) block models, contact detection algorithms, and time integration techniques. SOLFEC is particularly powerful in modelling element deformability with the help of FEM subdivision. In order to have reasonable computation times for real problems, parallelization is also applied in SOLFEC.

The approach of the Contact Dynamics method is very different from other discrete element techniques often applied for masonry analysis, 3DEC (Cundall, 1988) or DDA (Shi, 1992) for instance. In NSCD the basic unit of the analysis is the pair of two randomly chosen elements (contacting or non-contacting). The essence of the method is to find the contact forces transmitted between the two elements of the pair in such a way that during the analyzed time step the two elements should not overlap each other. The contact force is set to zero if the elements would not touch each other without this contact force even at the end of the timestep, and a non-zero vector is chosen (satisfying conditions corresponding to the mechanical behavior of the contact) if the two elements have to be slowed down in order to avoid overlap. So the motion of the system is numerically simulated in time through finite time steps, but in such a way that at the considered time instant an iterative process sweeps along randomly chosen pairs of the system over and over again, and gradually adjusts the estimated contact forces to get an improving approximation of a state that satisfies the dynamic equations of the system.

Contact recognition and the determination of its geometrical data (i.e. point of action of the contact force, and the normal direction) for polyhedral shapes require more sophisticated techniques than the treatment of spherical elements. The “common plane concept”, a very efficient solution of the problem, is an advantageous and widely applied possibility, and it will be introduced in a forthcoming section.

Most discrete element methods represent the deformability of the elements either by using an internal FEM mesh in the elements (e.g. 3DEC), or by concentrating the deformations into the contacts, like in the case of PFC (Cundall & Strack, 1979). The calculation of the contact forces between the elements are based on the stiffness characteristics of the contacts in those techniques. The philosophy of NSCD is different. According to the oldest NSCD models, the elements are perfectly rigid, and the contact forces are not related to any stiffness data: the contact forces are calculated to ensure the dynamic equations of the elements, and in addition, they must not violate requirements like the Coulomb limit for friction or the no-tension requirement in cohesionless contacts, but their calculation does not apply any constitutive relations. For statically highly indeterminate systems like e.g. a masonry wall, there exist several alternative force systems that satisfy the equations of motion; NSCD produces randomly one of them, while several equally valid solutions can be received if the problem is calculated repeatedly with the method.
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