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Nonsmooth Contact Dynamics for the Large–Scale Simulation of Granular Material

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Abstract

For the large-scale simulation of granular material, the Nonsmooth Contact Dynamics Method (NSCD) is examined. First, the equations of motion of nonsmooth mechanical systems are introduced and classified as a Differential Variational Inequality (DVI) that has a structure similar to Differential-Algebraic Equations (DAEs). Using a Galerkin projection in time, we derive nonsmooth extensions of the *SHAKE* and *RATTLE* schemes. A matrix–free Interior Point Method (IPM) is used for the complementarity problems that need to be solved in each time step. We demonstrate that in this way, the NSCD approach yields highly accurate results and is competitive compared to the Discrete Element Method (DEM).

Keywords: Granular Material, Nonsmooth Contact Dynamics, Friction, Interior Point Methods, Conical Optimization, Timestepping Scheme

1. Introduction

Granular material such as powders, pellets, sand and gravel are present in numerous engineering applications. The main loads acting on an excavator or wheel loader, for instance, result from the interaction of the shovel with the ground. A simulation framework to predict these loads is a desirable tool but still represents a great challenge today. Currently, two methods are mainly used: the classical Discrete Element Method (DEM) [1] and Non-Smooth Contact Dynamics (NSCD) [2, 3]. The DEM has shown its potential to deliver loads – the so-called draft forces – that are in agreement with experimental data [4]. But a simulation of a few seconds may take up days to weeks of computing time. On the other hand, NSCD provides a class of