Massively Parallel Non-Smooth Granular Dynamics and its Coupling with Lattice-Boltzmann methods

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ABSTRACT

All modern computer architectures are parallel. Since the speed of a single processor cannot be increased further only the number of transistors on each chip keeps increasing, leading in turn to an ever-increasing need for concurrency in program execution. In consequence, novel distributed parallel methods are required for all state-of-the-art computing. This is particularly true for demanding simulation tasks in science and engineering, such as simulations that require the processing of very large ensembles of distinct objects. In this work, we will introduce new parallel algorithms for non-smooth granular dynamics [1,2,5], i.e. for particles of fully resolved geometrical shape [3]. We will show that the parallel granular dynamics algorithms, including distributed contact detection and parallel contact resolution, scale up to the largest available supercomputers [4]. Examples with half a million processor cores and up to 10^{10} geometrically resolved particles will be demonstrated. In a second step, we will extend this methodology to the direct numerical simulation of particulate suspensions, by coupling the particle dynamics algorithm with a Lattice-Boltzmann-based fluid-dynamics solver [6,7]. The coupled algorithm will be applied to a scenario arising in the simulation of sediment transport in river beds [8]. A second example will be motivated by 3D printing as a modern additive manufacturing technology [9]. We will show how the process can be simulated by a complex combination of rigid granular dynamics and lattice Boltzmann methods. The scenario involves the generation of a powder bed, controlled energy transfer with an electron beam, melting of the particles, flow of the molten metal, and solidification [10]. With supercomputers, a direct numerical simulation is possible, i.e. representing the physics with full geometric and temporal resolution of each particle and modeling the melt flow subject to surface tension and contact angle conditions.

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