

Original article

Parallel collision detection of ellipsoids with applications in large scale multibody dynamics

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Abstract

This contribution describes a parallel approach for determining the collision state of a large collection of ellipsoids. Collision detection is required in granular dynamics simulation where it can combine with a differential variational inequality solver or discrete element method to approximate the time evolution of a collection of rigid bodies interacting through frictional contact. The approach proposed is structured on three levels. At the lowest level, the collision information associated with two colliding ellipsoids is obtained as the solution of a two-variable unconstrained optimization problem for which first and second order sensitivity information is derived analytically. Although this optimization approach suffices to resolve the collision problem between any two arbitrary ellipsoids, a less versatile but more efficient approach precedes it to gauge whether two ellipsoids are actually in contact and require the more costly optimization approach. This intermediate level draws on the analytical solution of a 3rd order polynomial obtained from the characteristic equation of two arbitrary ellipsoids. Finally, this intermediate level is invoked by the outer level only when a 3D spatial binning algorithm indicates that two ellipsoids share the same bin (box) and therefore could potentially collide. This multi-level approach is implemented in parallel and when executed on a ubiquitous Graphics Processing Unit (GPU) card scales linearly and yields a two orders of magnitude speedup over a similar algorithm executed on the Central Processing Unit (CPU). The GPU-based ellipsoid contact detection algorithm yields a 14-fold speedup over a CPU-based sphere contact detection algorithm implemented in the third party open source Bullet Physics Library (BPL). The proposed methodology provides the efficiency demanded by granular dynamics applications, which routinely handle scenarios with millions of collision events.

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Keywords: Collision detection; Ellipsoid; Parallel computing**1. Introduction**

Constraints in a multibody system can be classified as bilateral or unilateral. For holonomic systems, the former impose algebraic conditions that must be satisfied by the generalized coordinates used to capture the location and orientation of the rigid bodies in the dynamic system. They are associated with mechanical joints such as spherical, revolute, translational, and are discussed extensively in [13]. Unilateral constraints are associated with non-penetration conditions that arise in frictional contact dynamics when using, for instance, a differential variational inequality (DVI) approach to numerically determine the time evolution of the multibody system [1]. Contact detection is critical for

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