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Scaling Analysis of a Penalty Approach For Multibody Dynamics with Friction and Contact

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Abstract

Currently, the most common modeling and simulation software packages use penalty based methods to solve rigid body frictional contacts. The drawback to this is that the integration step sizes are very small, which leads to prohibitively large simulation times. In this report, seven simple multibody systems are modeled and simulated using the commercial software ADAMS. Each trial involves an increasing number of rigid bodies, and the resulting CPU time for a constant simulation time is recorded for the purpose of a scaling analysis. A short discussion rounds off the technical report.

Contents

1. Introduction

In order to reduce the time involved in multibody dynamic simulations that contain large numbers of rigid body contacts, new mathematical methods for solving these types of contact forces need to be investigated. Penalty based formulations are the current standard in most modeling and simulation software programs for solving rigid body contact problems involving friction. The drawback of this type of formulation is that the CPU time required for penalty based methods increases significantly with the number of colliding bodies, thus creating an upper limit on the number of colliding bodies that can be simulated in a reasonable amount of time. Systems containing hundreds of thousands or even millions of colliding bodies, such as simulations involving granular media, simply cannot be simulated using existing multibody dynamics codes.

This technical report investigates the CPU time required to simulate simple multibody dynamic systems in ADAMS, a commercial multibody dynamics package. The simulations involve dropping an increasing number of spherical bodies into a box for a fixed simulation time of 3 seconds. ADAMS utilizes the penalty method for resolving the frictional contacts between mutually interacting rigid bodies.

2. Simulation Procedure

This section provides information on how the system was modeled in ADAMS/View, as well as explanations of the simulation parameters. The unit system for the simulation was mm-kg-second.

The simulation of the system involved seven different trials, with each trial containing between 1 and 64 rigid spheres, falling into a box with a dimension of 800*800*800. All spheres were identical, each with a diameter of 60 and a weight of 0.882. The contacts were identical and defined between every rigid body in the simulation, with the following parameters: a stiffness of 1E5, force exponent of 2.2, damping coefficient of 10.0, and a penetration depth of 0.1. The initial position of the balls was generated randomly using function rand(), location = (740*rand()), (1.7*rand()), (740*rand()), and the initial velocity was set to zero. Simulations were stopped after the physical time reached 3 seconds. Each trial was run for the given simulation time, and the CPU time to complete the simulation was recorded. A movie clip of the simulation containing 64 spheres is provided below in Figure 1. Click on the figure to begin the animation.

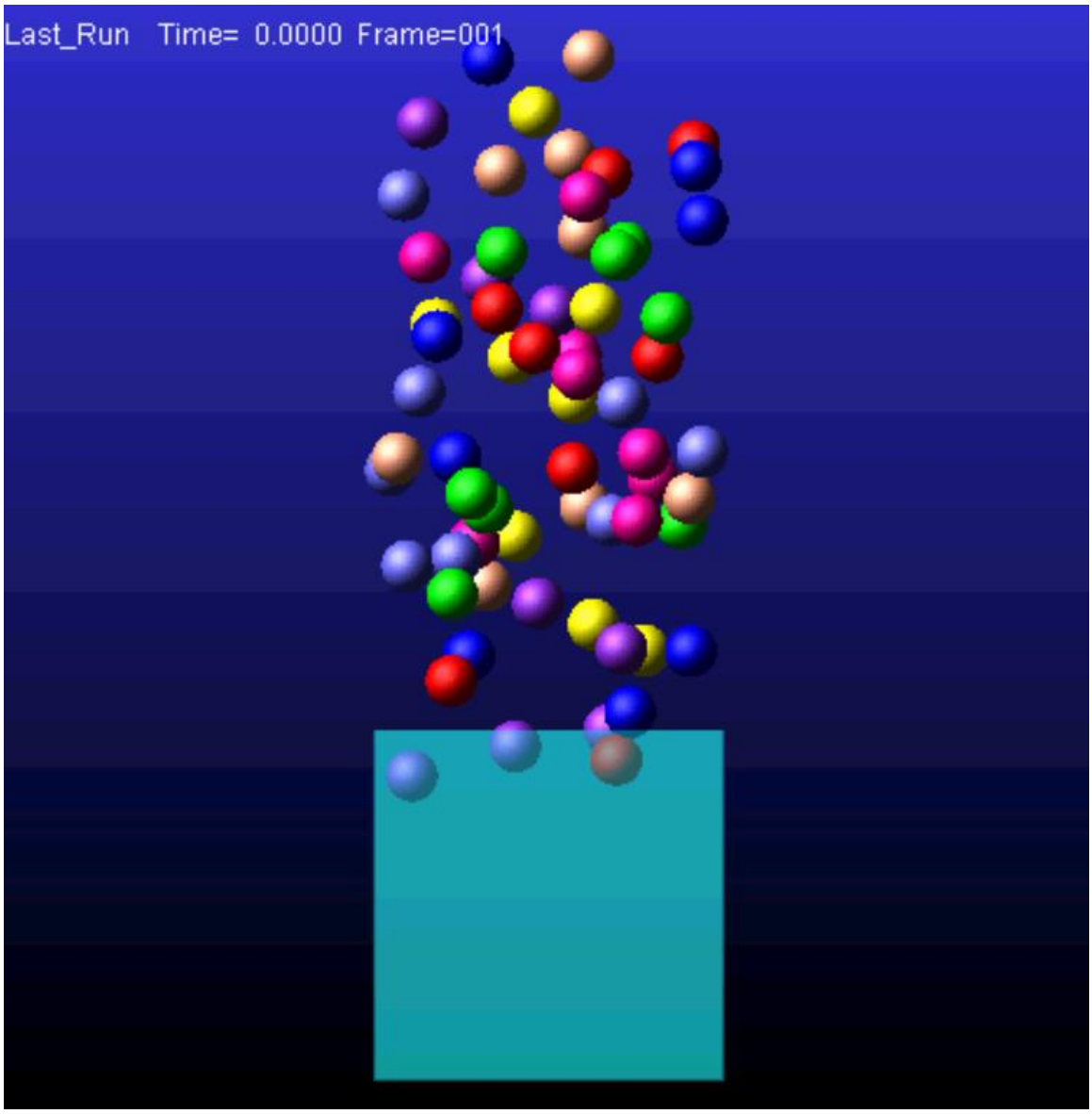

Figure 1: Simulation in ADAMS with 64 rigid spheres

3. Results

The following table shows the number of spheres in each trial, the corresponding maximum number of contacts for that system, and the resulting CPU time for the simulations carried out using ADAMS.

Table 1: Number of rigid bodies v. CPU time in ADAMS

Number of Spheres	Max Number of Mutual Contacts [-]	CPU time (seconds)
1	1	0.21
2	3	1.3
4	14	2.75

8	44	3.36
16	152	12.78
32	560	112.4
64	2144	603.27

Figure 2 shows the nonlinear increase in the CPU time as the number of colliding bodies increases. The trend line suggests that the nonlinear relationship is quadratic. Compared with Figure 3, which was generated in 2007 using the same simulation data[1], the results are similar since the CPU time both depend quadratically on the number of bodies in the system.

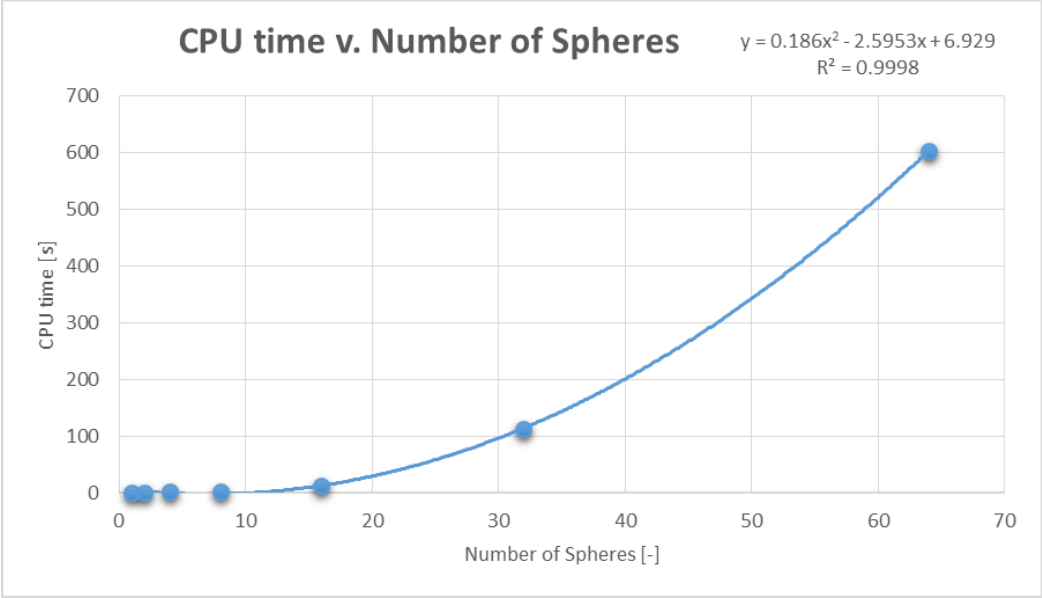

Figure 2: Nonlinear increase of CPU time in ADAMS in 2013

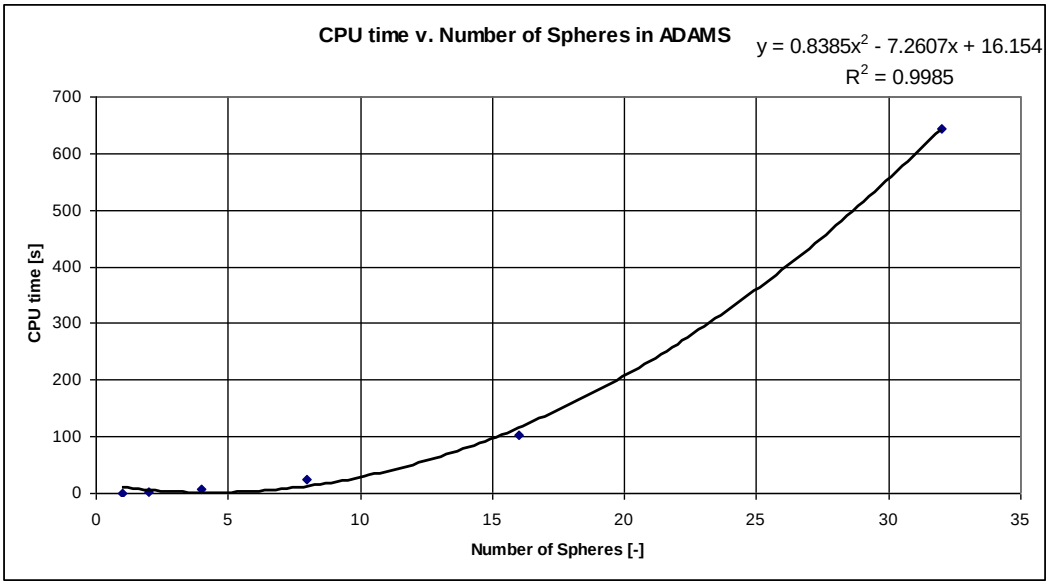

Figure 3: Nonlinear increase of CPU time in ADAMS in 2007

4. Discussion

ADAMS is limited in its use of frictional contact by its nonlinear increase in CPU storage space and time as the number of colliding bodies increase.

5. References

[1] TR-2007-06: "Penalty Versus Complementary-Based Frictional Contact of Rigid Spheres: a CPU Time Comparison" J. Madsen, N. Pechdimaljian, D. Negrut