Spatial Hashing and Parallel Collision Resolution for Efficient Simulation of Systems of Ideal Particles

by

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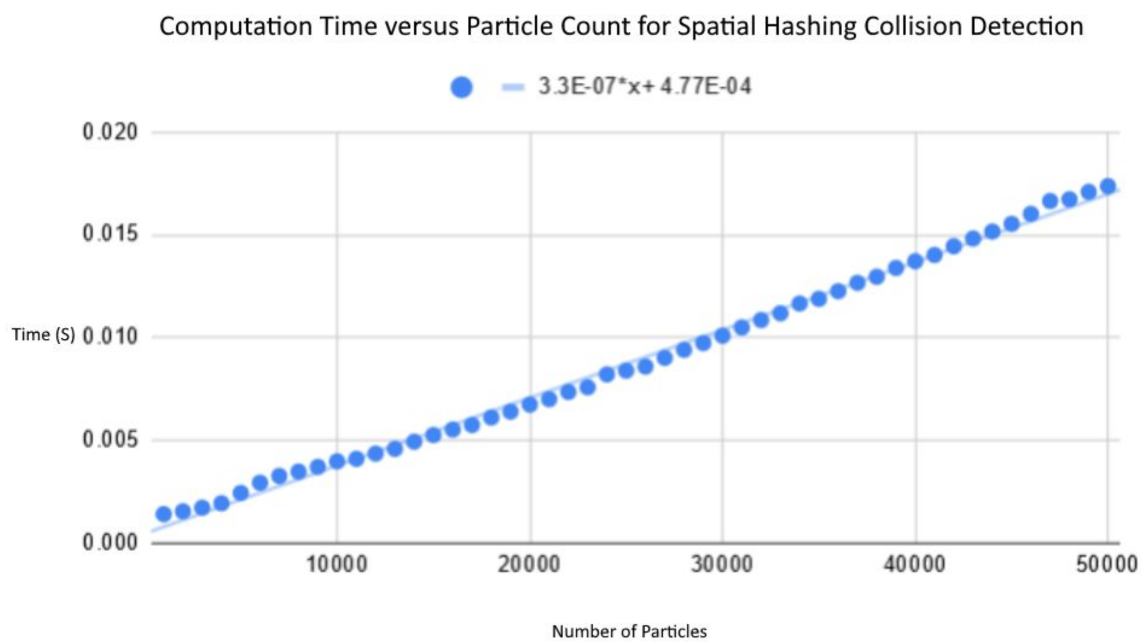
https://github.com/benschreyer/ParticleSimulator

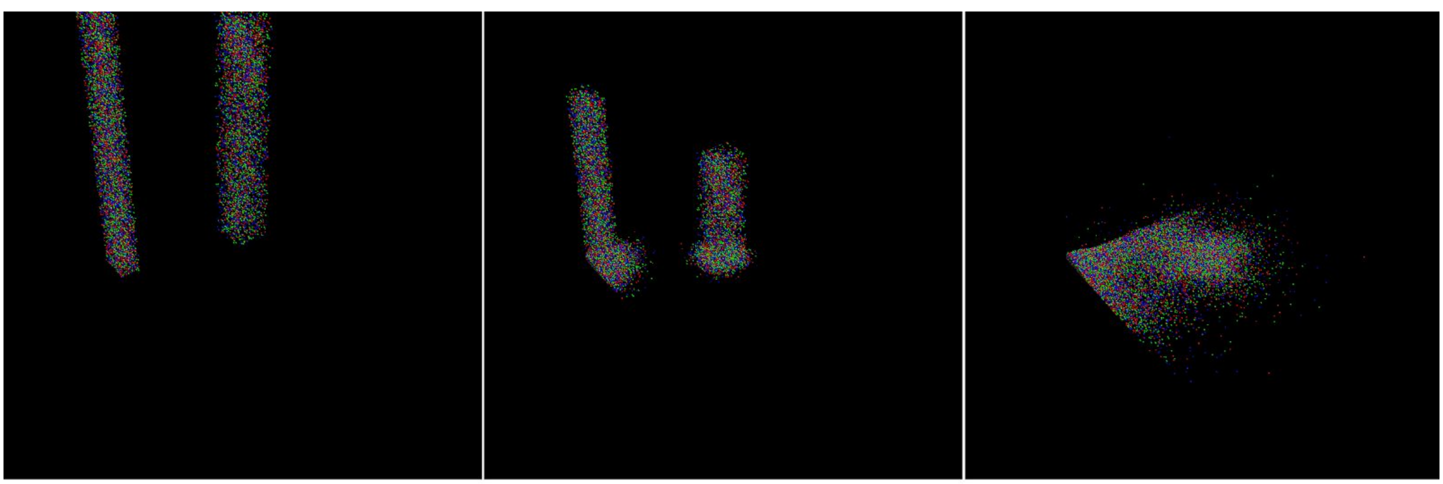
Abstract

Discrete and uniform particles can be used to model many physical systems. Strong examples are ideal gases or large collections of sand or other particulates. With increased model complexity such as cohesive forces things like liquids, fabrics, or solid material can be simulated as well. All of these applications can be made to rely on a collision algorithm to determine when an interparticle force is no longer negligible or when an elastic collision should occur. A naive approach to collision checking between objects has a time complexity of $O(n^2)$ leading to simulating larger systems becoming increasingly difficult. A typical computer will struggle to compute collisions between 10,000 ideal gas particles using the most obvious approach to computation. This paper explores the use of hashing algorithms on the spatial coordinates of particles to allow for $O(n)$ computation complexity when detecting collisions between similarly sized objects(about within the same order of magnitude). Example simulations picked from the mentioned systems above will also be covered. Theoretical calculations and automated testing have revealed that the algorithm developed has time complexity $O(n)$. For the case of simulating ideal gas particles on a personal computer with a graphics card about 10 times as many gas particles were able to be simulated with the same time step and processing time as the naive approach. For simulation of more complex structures like cloth speed improvements are closer to a constant reduction of one half instead of a decrease in the degree of the time complexity.

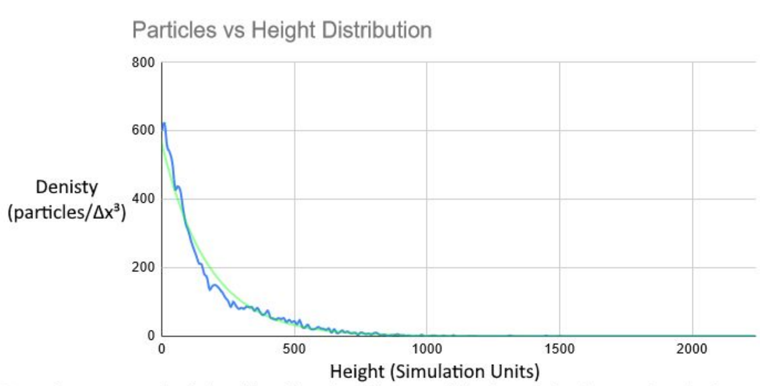
Performance Testing



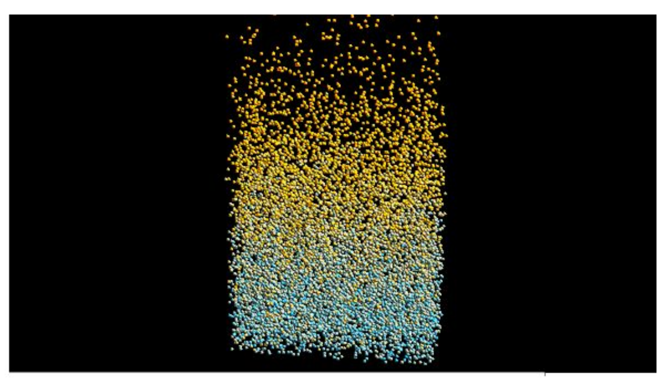
Example Applications



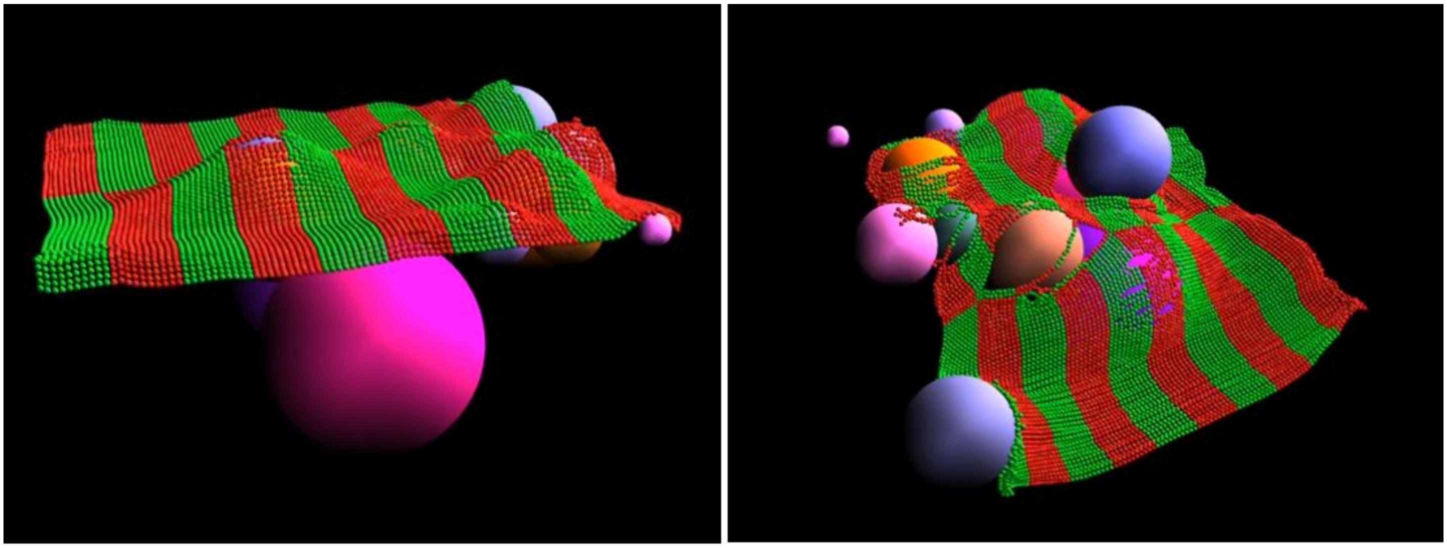
Time evolution of 100,000 bouncy balls with spatial hashing collision algorithm



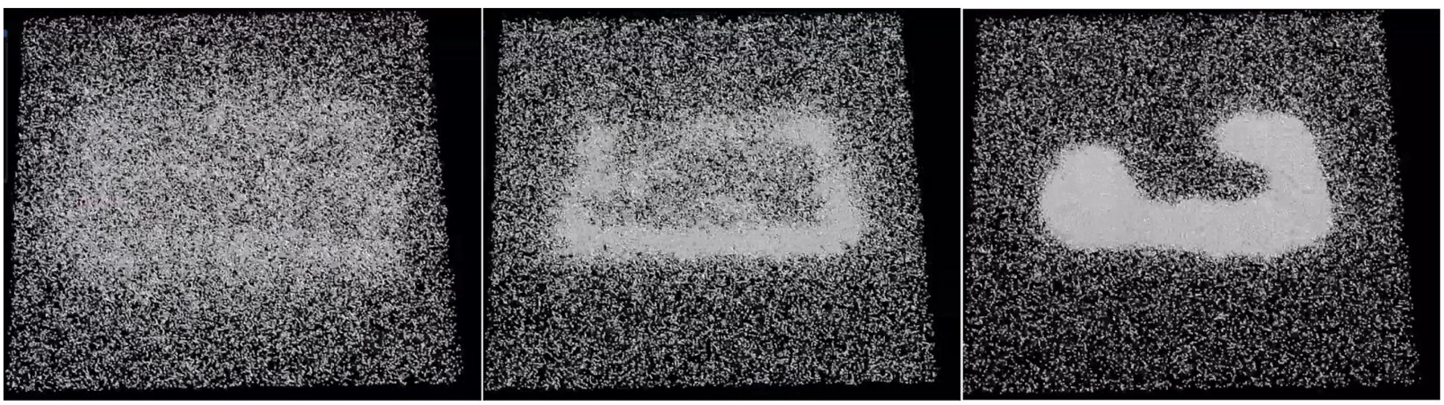
Density versus height distribution for equilibrium ideal gas simulation and parameter fit exponential curve for atmospheric gas density at altitude



Non-equilibrium state of gas column simulation with kinetic energy coloring



Rippable cloth simulation with spatial hashing collision detection



Surface tension in container of sand vibrating at 30hz