Fast Sphere Packing with Adaptive Grids on the GPU

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Motivation
Previous Work

- Dense packings

- Fractal Properties of Dense Packing of Spherical Particles
  - Adil Amirjanov and Konstantin Sobolev, 2006

- Three-Dimensional Apollonian Packing as a Model for Dense Granular Systems
  - V. Anishchik and N. N. Medvedev, 1995

- Protosphere: A GPU-Assisted Prototype Guided Sphere Packing Algorithm for Arbitrary Objects
  - R. Weller and G. Zachmann, 2010
Protosphere Recap

- A greedy approximation of Voronoi nodes
Protosphere Recap

• Method:

1) Place Prototype inside object
2) Find closest point on objects hull
3) Move prototype away from closest point
Protosphere Recap

- Parallisation: Uniform Grid

Every cell stores:
- References to all triangles intersecting it
- References to all spheres intersecting it
- Discrete distance to the next cell with triangles or spheres
Protosphere Recap

- Naïve parallelisation: one core for every prototype
- Actual parallelisation: one core for every cell in the discrete distance to each prototype
Protosphere Recap

Starting efficiency low (many Prototypes but few new spheres)

Fill rate at the end depends on predefined resolution
Implicit Grid Refinement

- We need: coarse grid at the start, fine grid at the end
- Idea:
  - Split every cell periodically into $2^n$ new cells
  - Decouple the prototypes from the triangle data
Implicit Grid Refinement

- Higher degree of parallelisation
- Predefined maximal grid resolution
Adaptive Grid Storage

- End performance depends on fine grids
- Fine grids need a lot of memory
- Idea: save only cells inside or on the border of the object

~22% outside

~34% outside
Adaptive Grid Storage

- Working Array:

- Address Array:

- Index in the grid:
Explicit Grid Refinement

- We need: refine the grid while packing the object
- Idea: Split every cell in the data grid periodically into $2^n$ new cells
Explicit Grid Refinement

Good performance when splitting to very fine grids at the end.

Many triangle-to-point-tests for one prototype at the start.
Hybrid Grid

- Combines the explicit and implicit grid refinements
Demonstration
Results

- Objects used: (up to 800k triangles)

- Objects filled: (about 200k spheres)
Results

Protosphere Recap          Explicit Grid            Implicit Grid          Adaptive Grid Storage          Hybrid Grid              Results
Conclusion and Future Works

- Hybrid Grid is 100 times faster than Protosphere
- 200,000 spheres and 95% coverage in ~30 seconds
- 80% coverage in less than 10 seconds
- First iteration in near real-time (~0.05 seconds)
- Optimal parameter guessing based on object
- More object representations
- Testing more grid-like data structures