Interactive Ray Tracing of Complex and Dynamic Scenes

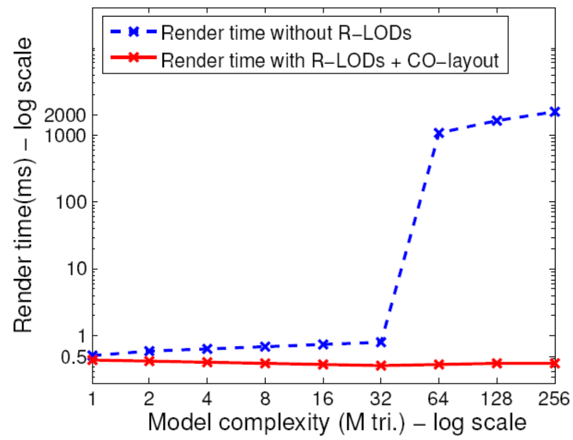
Background and Challenge

Ray Tracing is a fundamental method used in computer graphics and other simulations such as for RF propagation sound rendering, line-of-sight queries for modeling and simulations. There is a renewed interest in real-time ray tracing due to the exponential growth rate of processing power. However, current ray tracing algorithms have two disadvantages: the behavior of ray tracing degrades significantly when rendering models that are too large to fit into main memory, and precomputed static acceleration structures prevent the use of dynamic environments. Our research aims to address these problems.

Ray tracing massive models

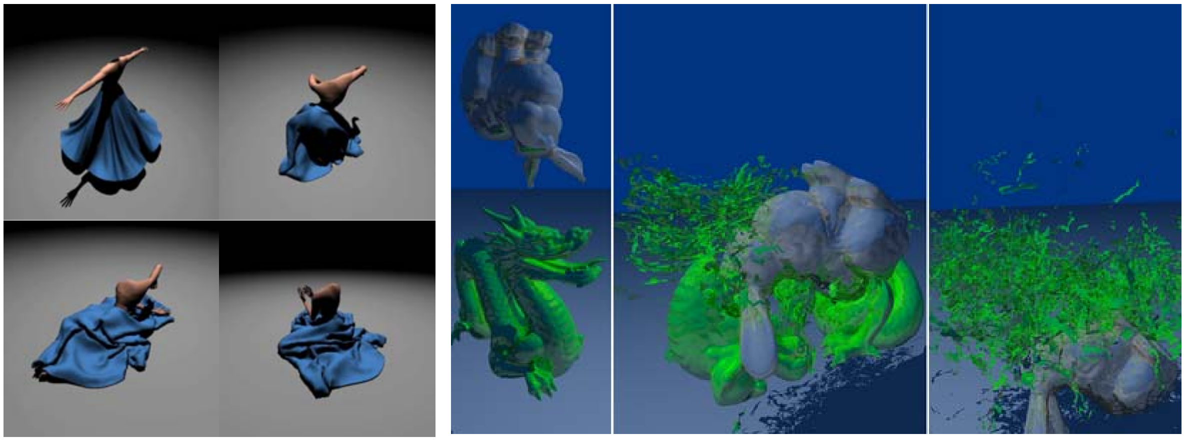
We introduce a novel representation and algorithm based levels-of-detail for ray tracing, called R-LODs. R-LODs are a lightweight planar LOD representation that is designed with low memory overhead and efficient runtime use in mind. Each R-LOD is directly integrated with the nodes of the hierarchical representation. During runtime traversal of the hierarchy, our efficient LOD metric decides which LOD level to use per ray based on the introduced error. This allows us to limit the visual impact of R-LODs to sub-pixel effects which in practice result in almost no perceivable difference in image quality. Moreover, we have observed that R-LODs can even decrease temporal aliasing artifacts when rendering. We have tested our algorithm on models from tens to hundreds of millions of triangles and have observed a speed-up of 2-20 times in rendering performance compared to standard ray tracing due to better memory coherence and lower memory set size.

We have also designed new memory-efficient representations for ray tracing massive models. We introduce Ray-Strips, which are a compact lossless representation of triangular models for use in interactive ray tracing. By representing the model with triangle strips and then defining a lightweight hierarchy on the strips, we reduce the memory needed for triangle representation as well as acceleration structure. Our results show that Ray-Strips reduce the memory requirements for a range of common models by 70-80% compared to current representations in ray tracing. This can improve the runtime performance on massive models due to a reduced memory footprint.



Logarithmic ray tracing behavior as the complexity (in millions of triangles) of the same model increases. When the size of the geometry and hierarchy exceeds main memory, rendering time increases drastically.

128 million triangle St.Matthew statue rendered at interactive frame rates using our R-LOD approach



Several frames from dynamic deformable models rendered using our BVH system. *Left*: Deformable cloth simulation (14k triangles) rendered in real time at interactive frame rates using BVH updates. *Right*: 252k triangle model of a breaking object simulation rendered by selective restructuring.

Ray tracing of dynamic scenes using BVHs

Previously, interactive ray tracers have used static hierarchical data structures for representing input models to achieve real-time performance. We show that dynamic BVHs (bounding volume hierarchies) can be used with current ray coherence techniques such as ray packets and frustum culling to achieve similar performance improvements for ray tracing. BVHs can be updated quickly to account for deforming geometry and therefore do not have to be rebuilt when the scene is animated. In addition, BVH updates can also be parallelized with near-linear scalability, and thereby ray trace many dynamic scenes at 3-13 frames per second on a variety of models using a normal desktop PC.

One issue with BVH updates is that incoherent movement of primitives such as breaking objects may decrease the quality of the hierarchy, leading to a decrease in performance. We present two different approaches to address this problem, a heuristic that detects degradation automatically based on relative overlap, and a more general approach that uses selective rebuilding to identify and rebuild affected sub-trees for better scalability. This allows us to maintain BVH quality constantly for any kind of animation.

Members

Dinesh Manocha
Sean Curtis
Christian Lauterbach

External Collaborators

Sung-Eui Yoon

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Publications

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