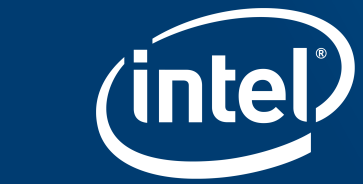
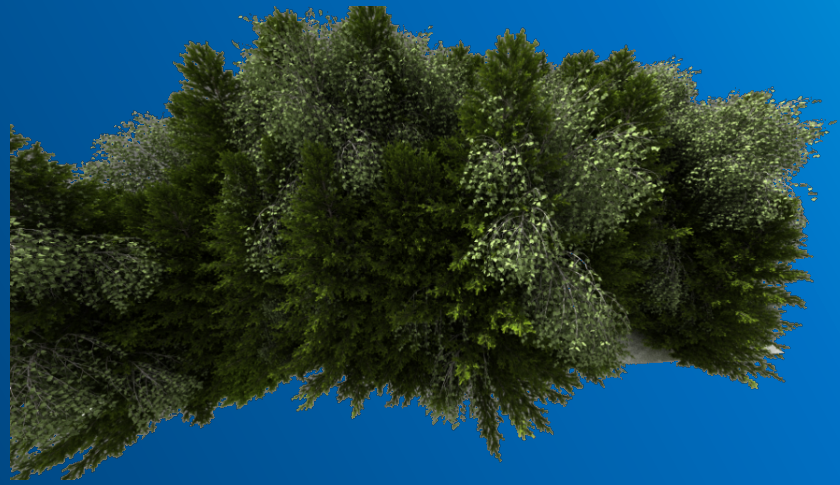


Improved Two-Level BVHs using Partial Re-Braiding

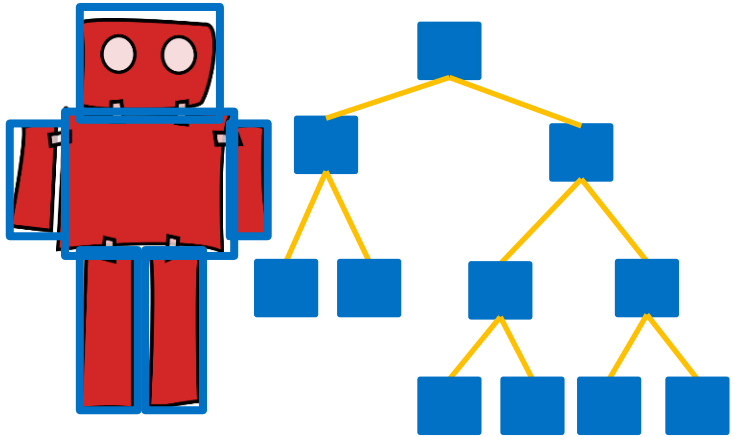
Carsten Benthin, Sven Woop, Ingo Wald, Attila Áfra

HPG 2017



Recap

- Two-level BVH
  - Multiple object BVHs
  - Single top-level BVH



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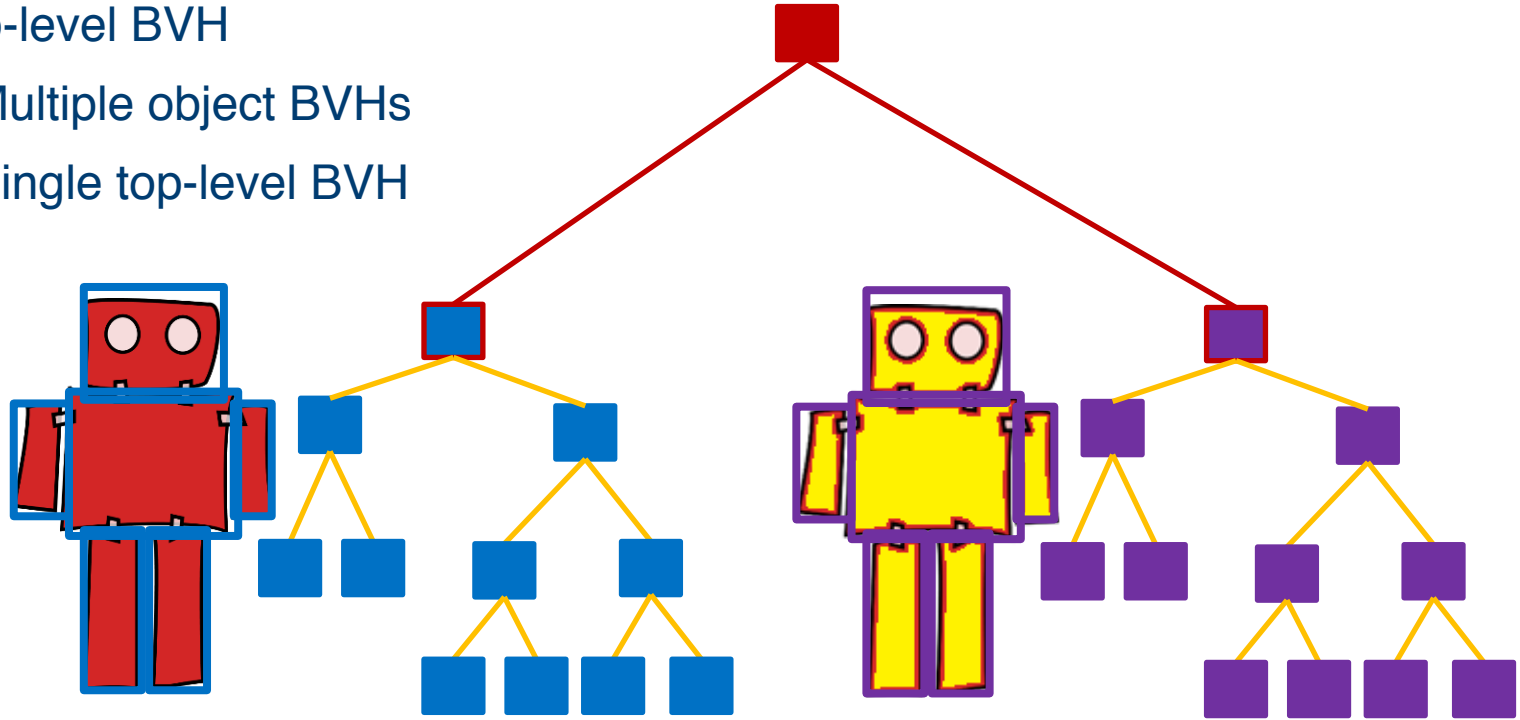

Motivation

- The “Library Incident”

Motivation

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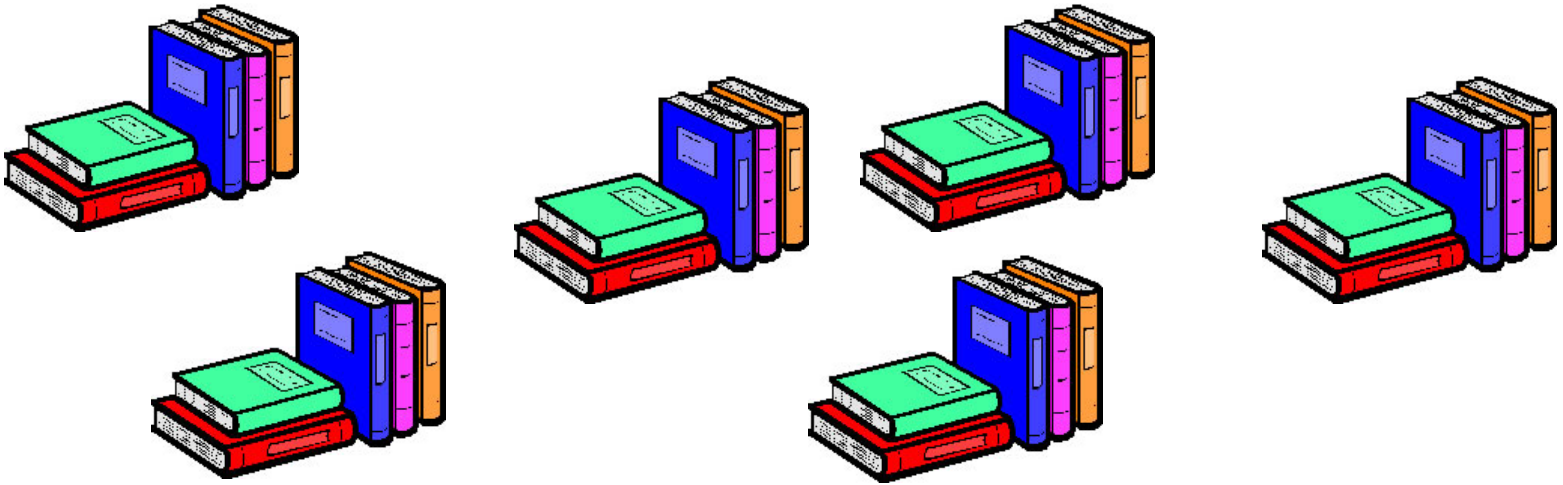

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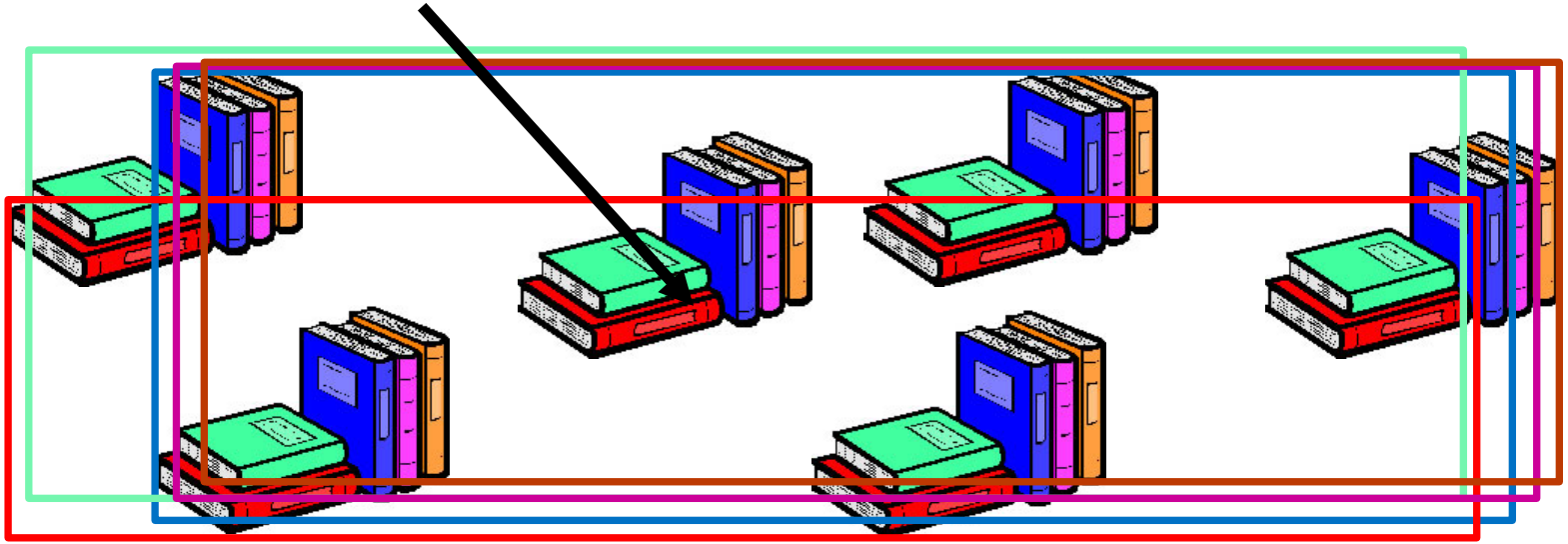


- Objects based on material ➔ large overlap of object bounds!
- Ray traverses many objects

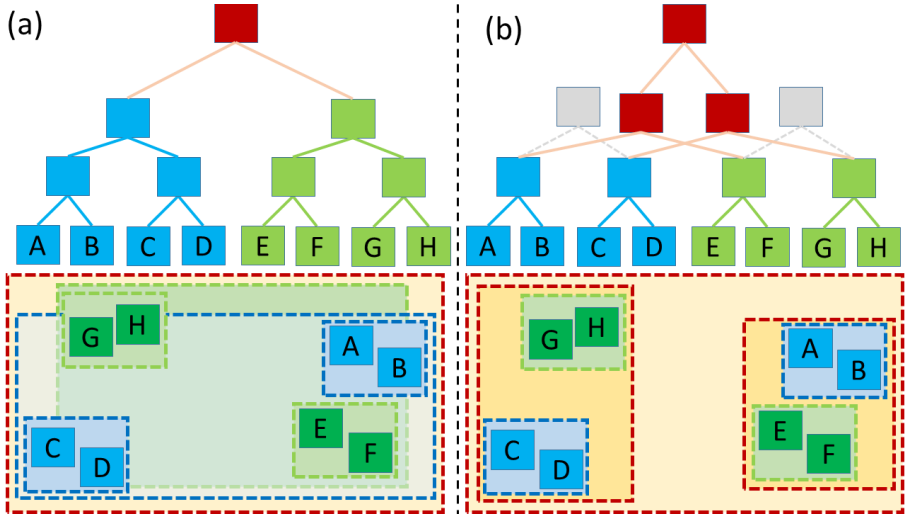
How to improve two-level BVHs with large spatial overlap?

- Fix object grouping
  - Often grouping can‘t be changed easily
  - Cannot avoid object overlap in general

- Build a single, flat BVH
  - Slow build performance
  - Issues with partial updates (dynamic scenes)
  - Instancing

General Idea

- Open up object BVHs to find subtrees with less overlap
- Rebuild top-level BVH over these subtrees
- Let new top-level BVH reach „deep“ into object BVHs



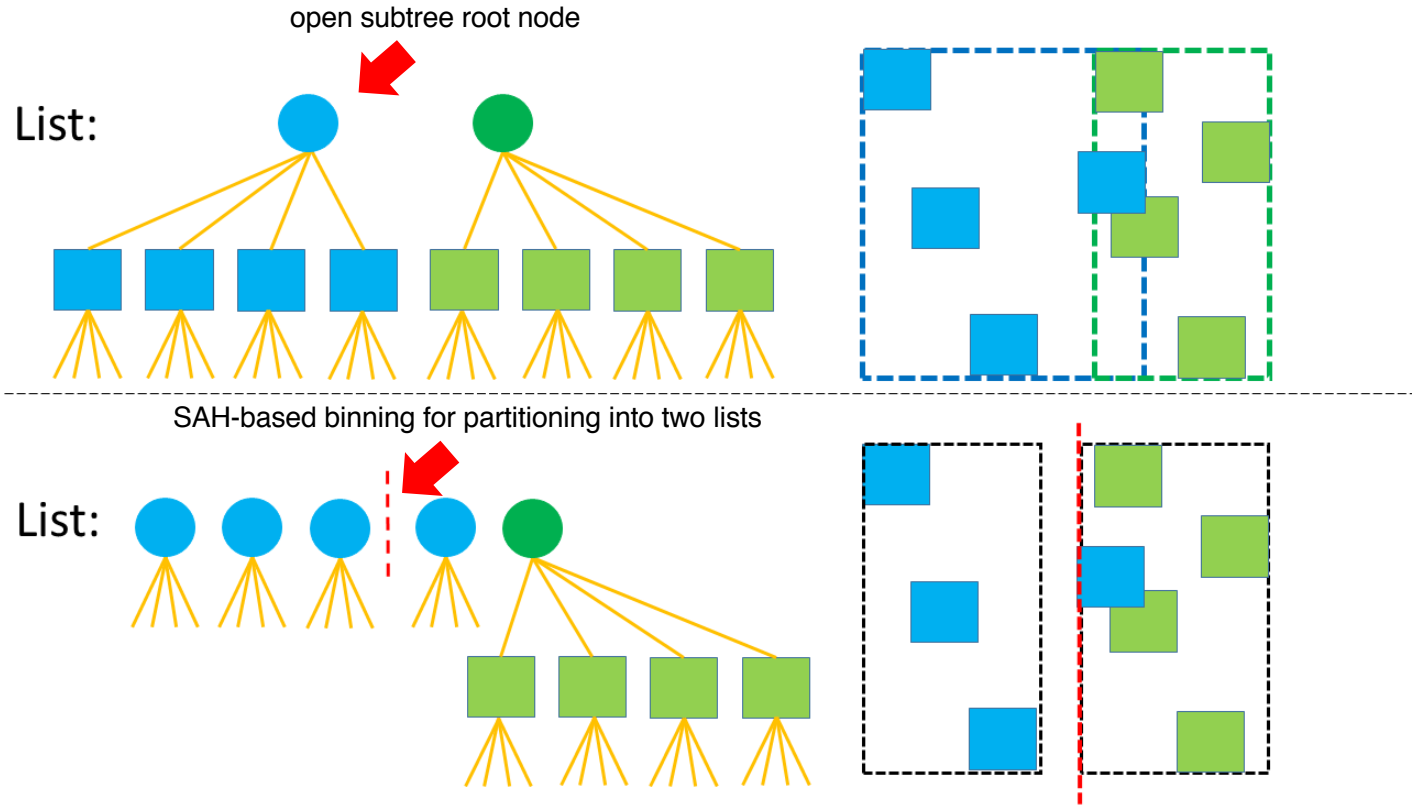
But…

- Which object should be opened?
- When should we stop the opening?
- How and when do we build the new top-level BVH?
- How do we efficiently parallelize the opening and top-level build phase?

Our Approach

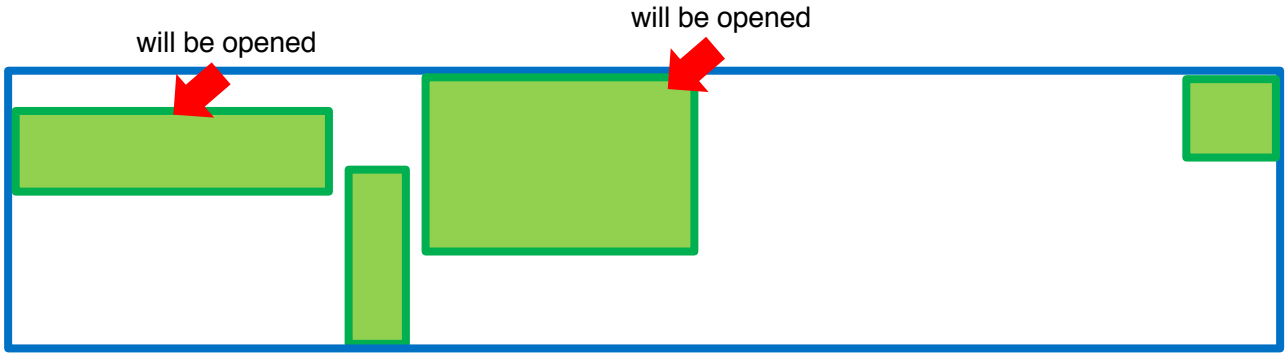
- Maintain a list of subtree nodes (initialize with object BVH root nodes)
- In each top-level BVH builder step:
  - First check if node opening should be done for current node list
  - If yes, iterate over list and mark nodes which meet opening criteria
  - Open marked nodes by replacing them with their children
  - Apply SAH-based binning step to partition list into two sub-lists
  - Continue recursively with the two sub-lists

Our Approach



Node Opening Criteria

- Node opening criteria
  - Compare node‘s AABB to AABB over entire list
  - Pick dimension **d** where extent is largest
  - Open node if its extent (in **d**) is > 10% than list extend

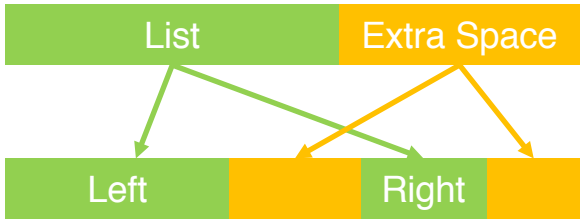


Opening Phase Termination

- Stop subtree node opening for given list if
  - All subtree nodes in list belong to the same initial object
  - There‘s no overlap between nodes (only tested for short lists)
  - No more memory is available to store children of opened nodes

Memory Handling

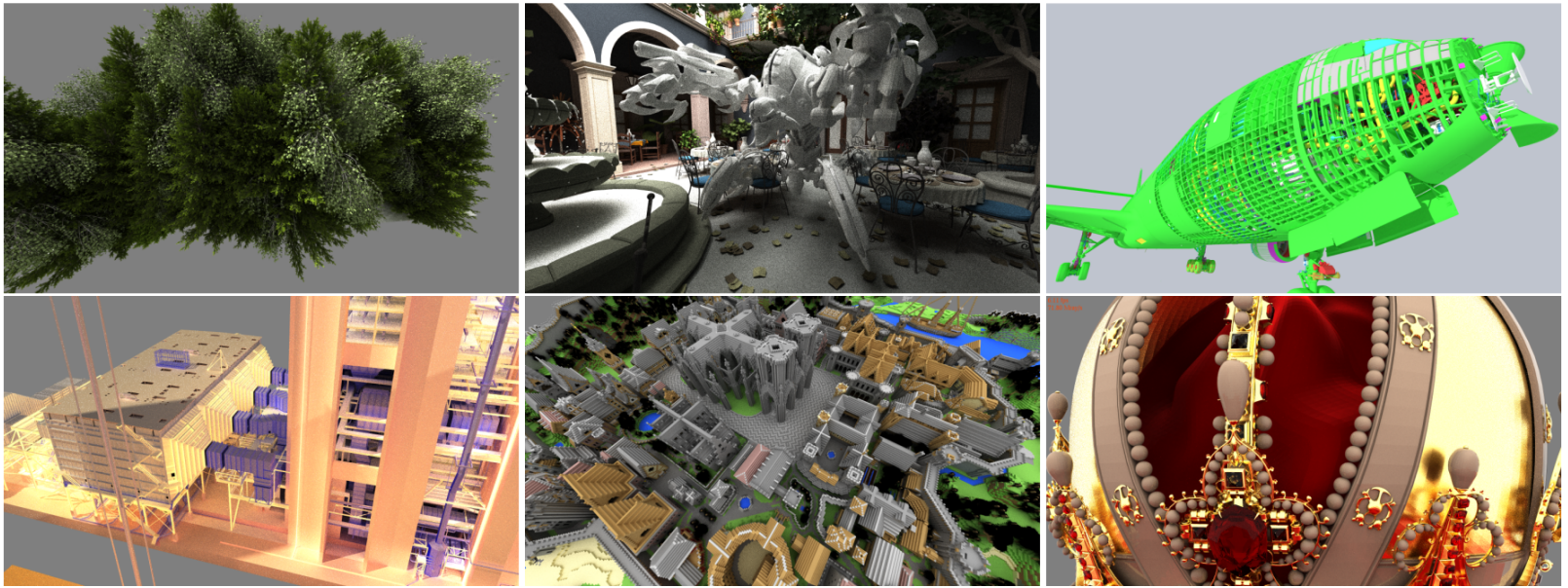
- Node opening lets list grow quickly
- Allocating system memory during top-level build is too costly
- Use pre-allocated memory block for holding list data
- Memory block has „extra“ space for new entries
  - Similar to spatial split BVH builders [Ganestam 2016, Fuetterling 2016]
- Distribute „extra“ space heuristically during recursion



Parallelization

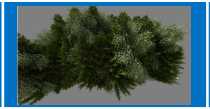
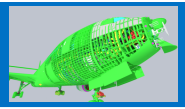
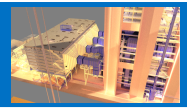
- Recusively spawn tasks when processing left and right sub-lists
- Parallize opening, binning, partition phases for lists with many entries
- Need to exploit nested parallelism
- TBB ➔ very good scalability in #threads

Results

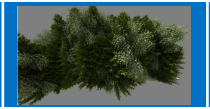
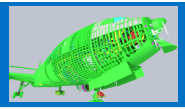
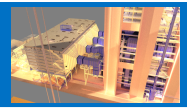


- Integrated our approach into Embree
- Path tracing for comparing rendering performance
- Dual-socket Intel Xeon E5-2699 v3 (36 cores total) with 64 GB of memory

Rendering Performance

						
objects	8	253	720,849	56	84	850
instances	12,000	-	-	-	-	-
triangles	522M	10.5M	330M	12.3M	6.7M	4.8M

Rendering Performance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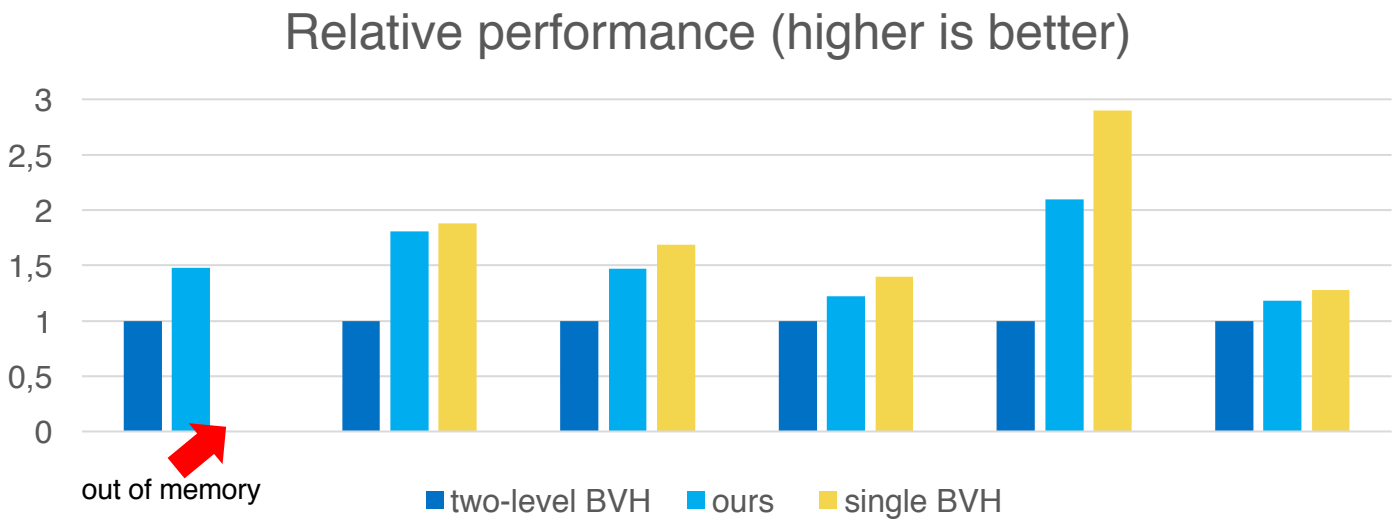
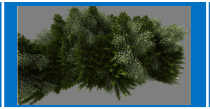
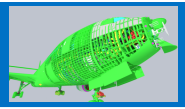
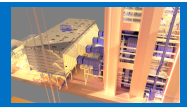


BVH Build Performance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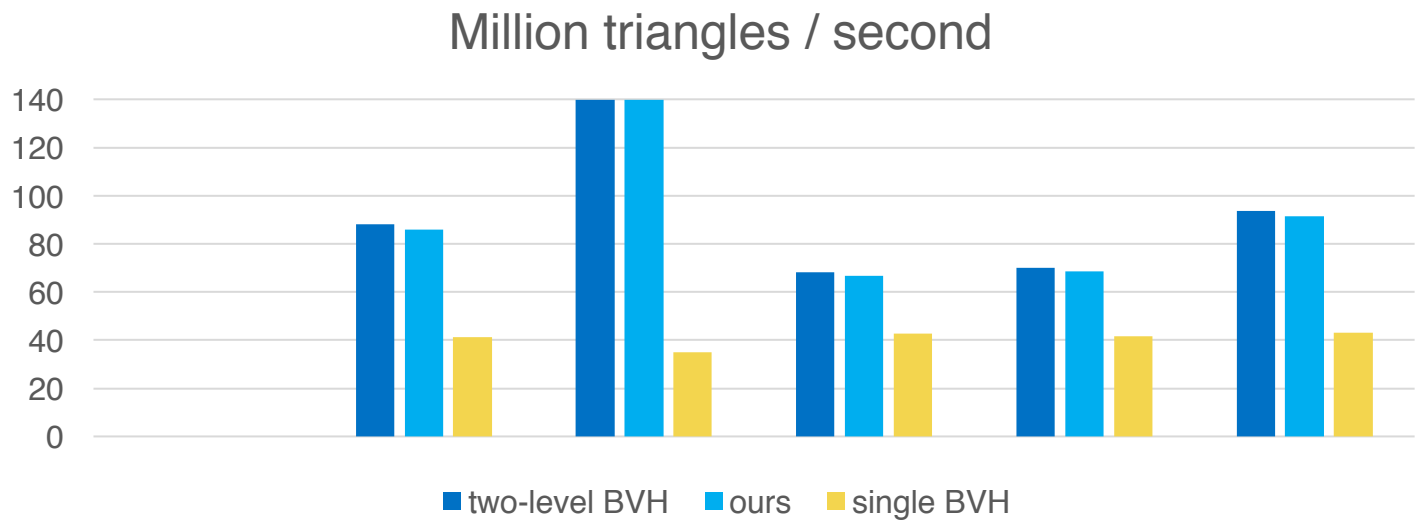

Dynamic Scenes

San-Miguel + Animated Robot

254 objects
10.3M static triangles
200K dynamic triangles
per frame: key-frame interpolation, dynamic object BVH rebuild, top-level BVH rebuild
1920x1080 resolution, single rays

Conclusion & Future Work

- Partial Re-Braiding significantly reduces spatial overlap in two-level BVHs
  - Improves overall BVH quality ➔higher rendering performance
  - Adds just little overhead to top-level BVH builder (always on)
  - Good fit for partial updates in dynamic/static scenes

- Integrated into Embree 2.16
- In the future focus on
  - Better opening heuristics, leaf opening and improved overlap detection
  - Combine with ideas from [Hendrich 2017]

Questions…

https://embree.github.io

Demo at Intel SIGGRAPH Booth

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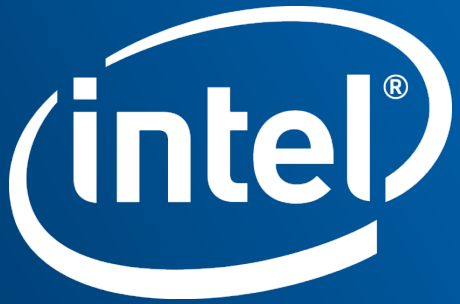
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