



Improved Two-Level BVHs using Partial Re-Braiding

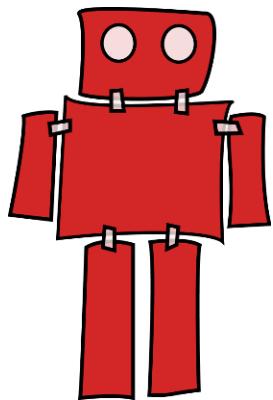
Carsten Benthin, Sven Woop, Ingo Wald, Attila Áfra

HPG 2017



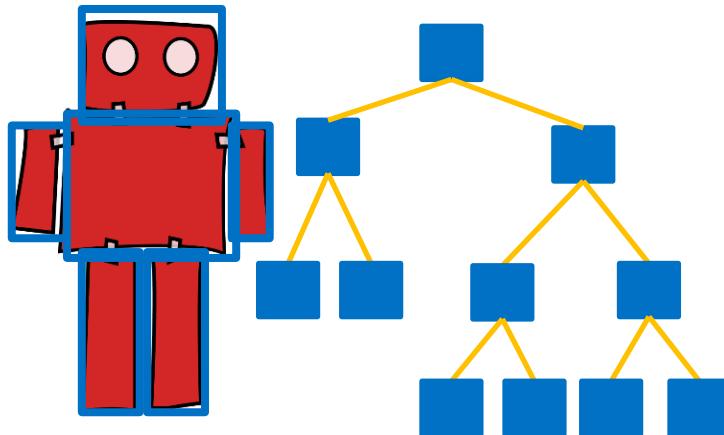
Recap

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



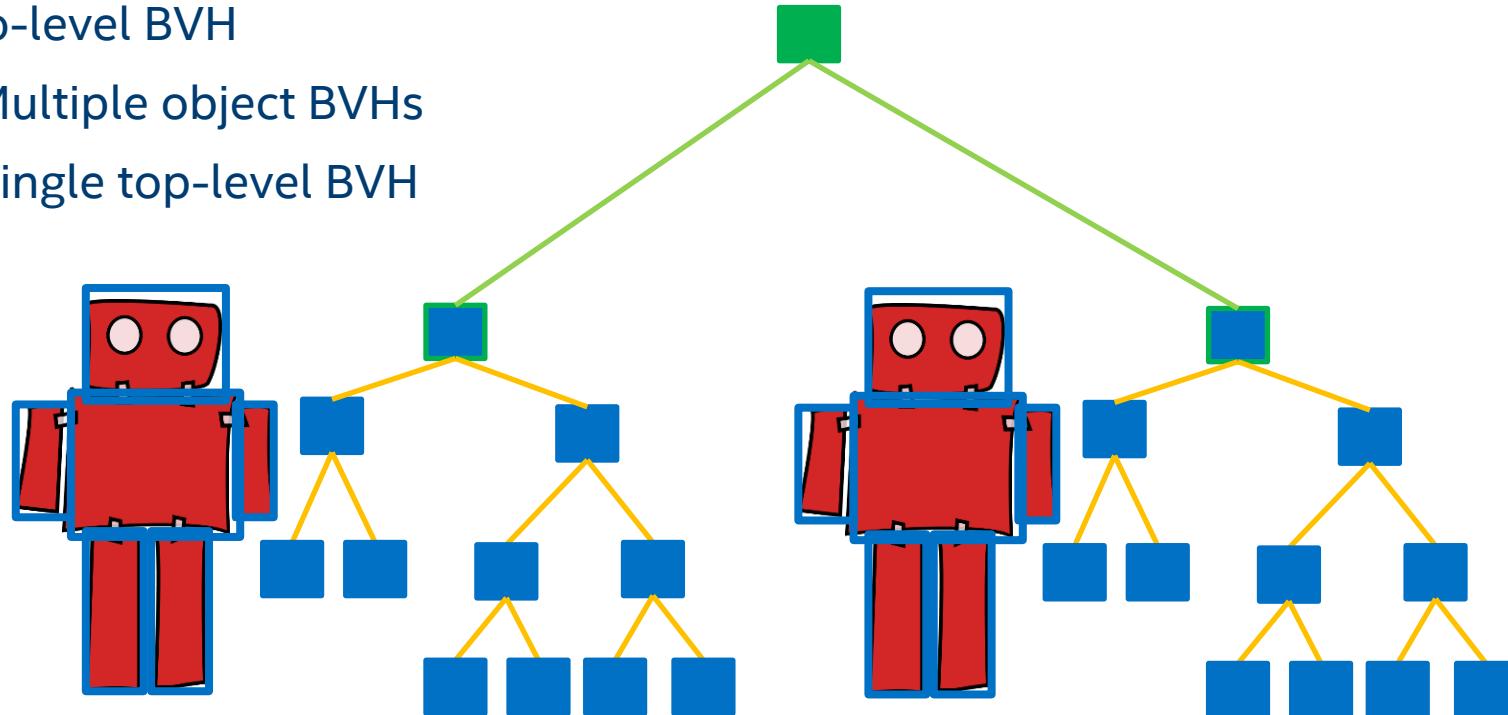
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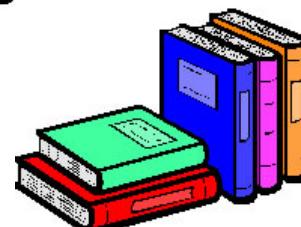
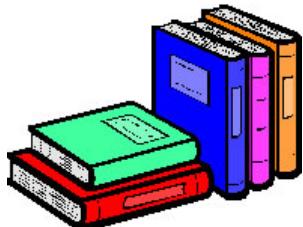
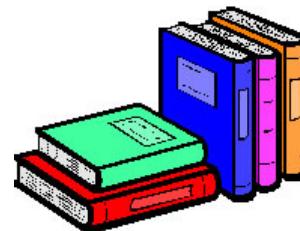
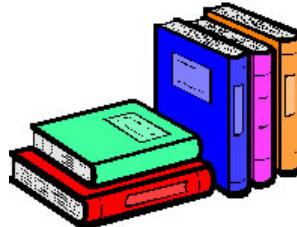
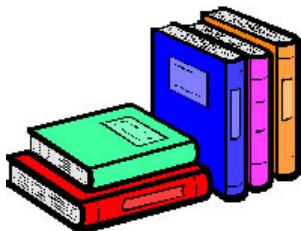


Motivation

- The “Library Incident” or your two-level BVH “sucks”...

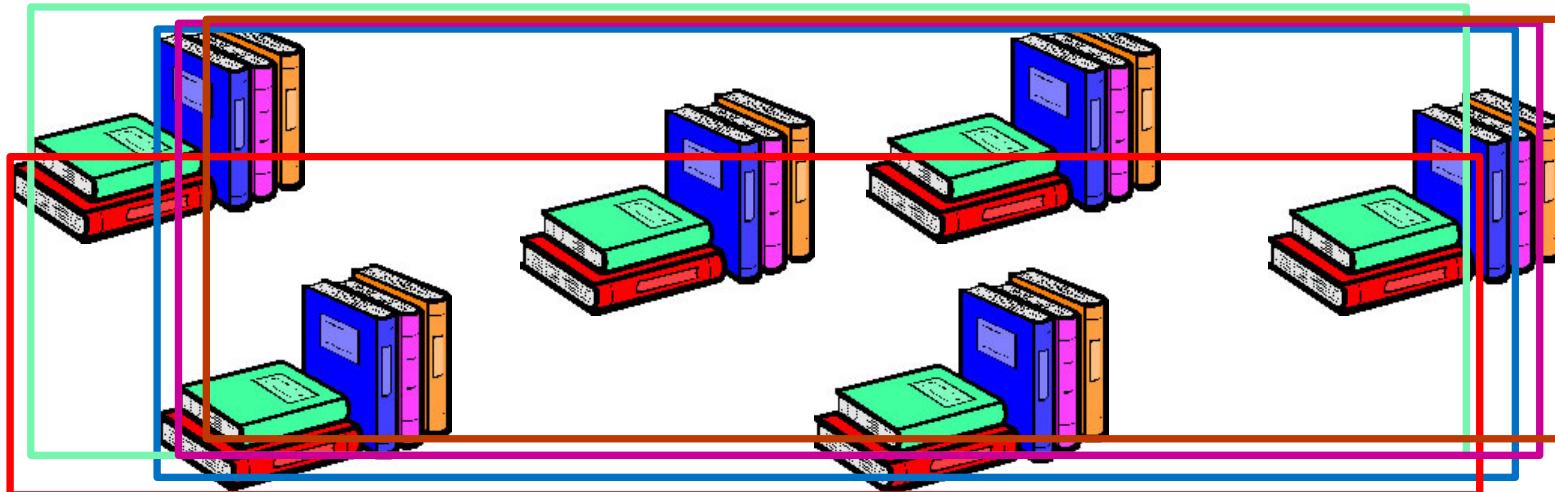
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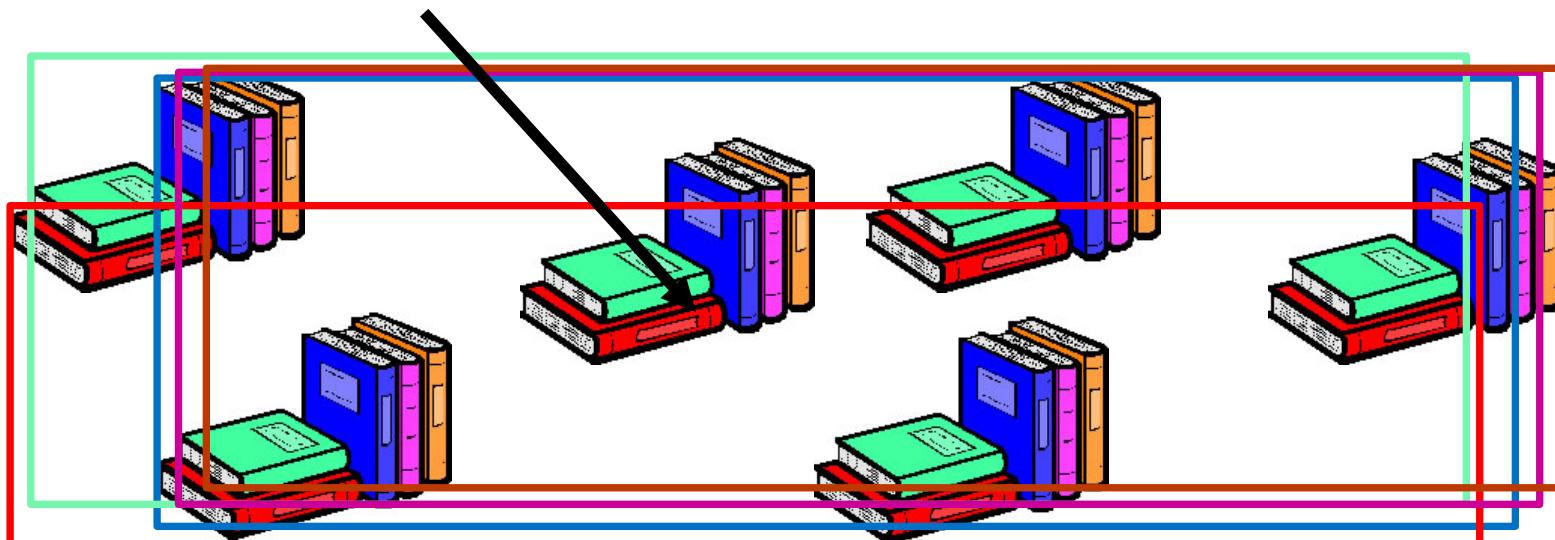
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- Objects based on material → large overlap of object bounds!

Motivation

- The “Library Incident” or your two-level BVH “sucks”...

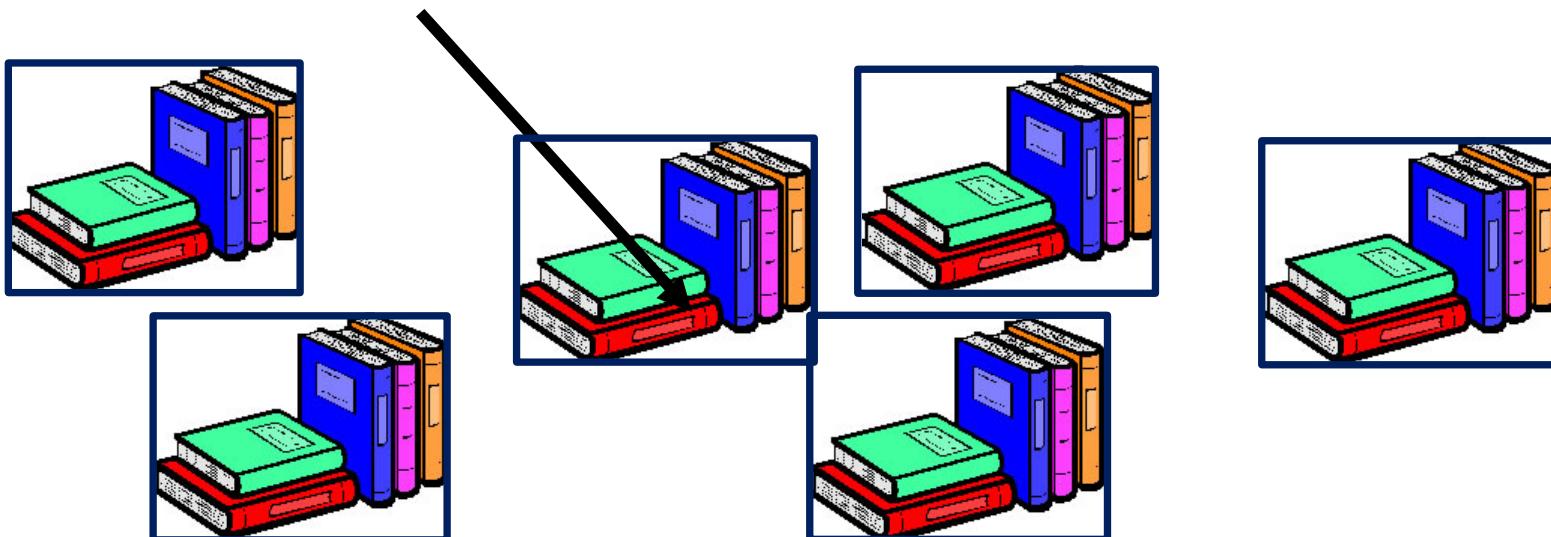


- Objects based on material → large overlap of object bounds!
- Ray traverses many objects



Motivation

- The “Library Incident” or your two-level BVH “sucks”...



- Spatial object grouping → far less overlap of object bounds
- Ray traverses just single object

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

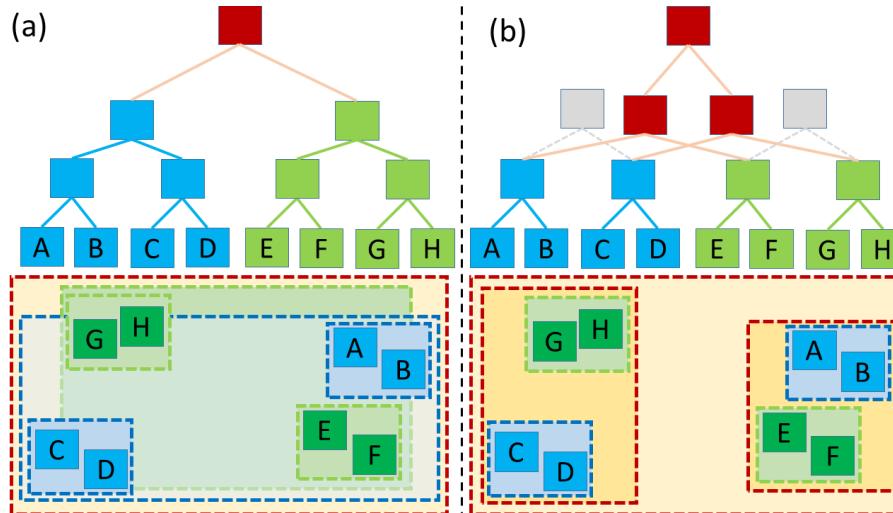
- Fix object grouping in the application
 - Often grouping can't be changed easily
 - Cannot avoid object overlap in general
- Build a single, flat BVH
 - Slow build performance
 - Issues with partial updates (dynamic scenes)
 - Instancing

General Idea

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

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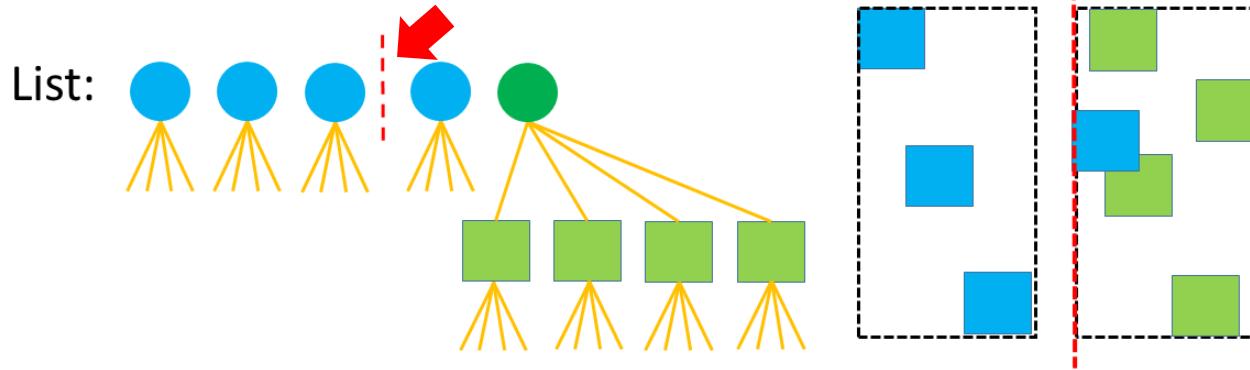
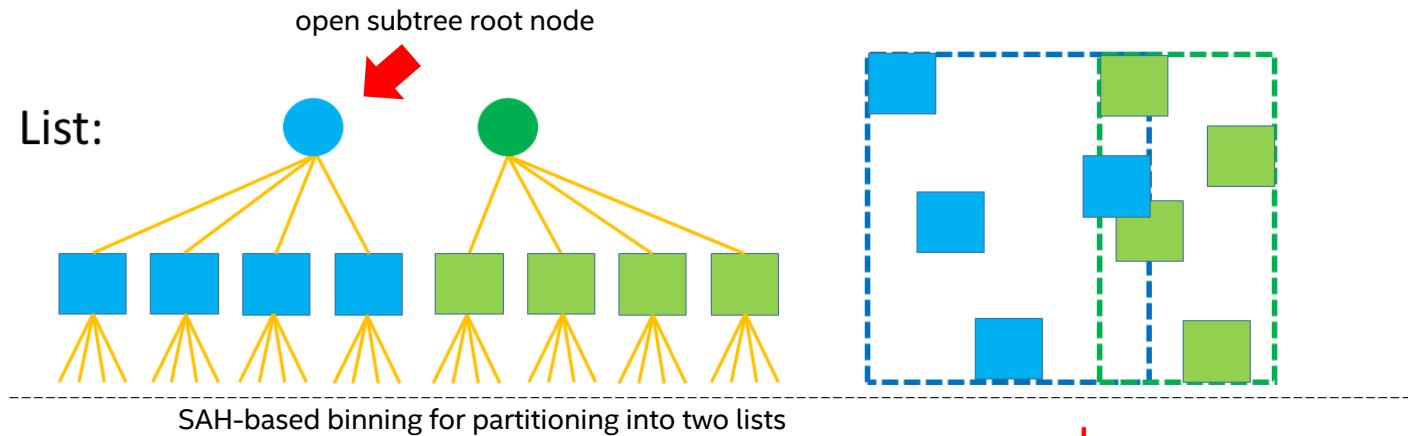
But...

- 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 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

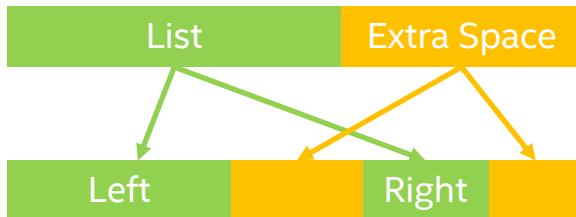
- Node opening criteria
 - Compare node's AABB to AABB over entire list
 - Pick dimension **d** where extend is largest
 - Open node if its extend (in **d**) is > 10% than list extend
- Nodes more equally sized after couple of opening iterations

Opening Phase Termination

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

Memory Handling

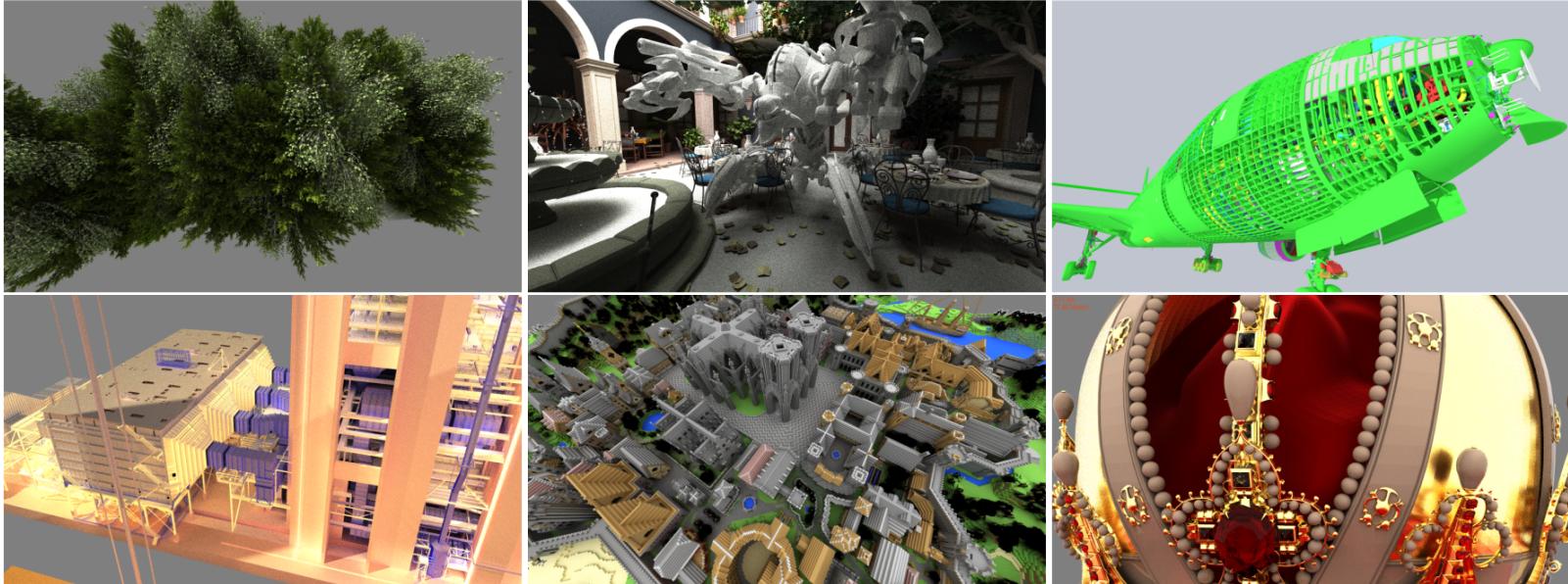
- Node opening lets list grow quickly
- Allocating/deallocating system memory during top-level build is too costly
- Use pre-allocated memory block for holding list data
- Memory block has „extra“ space for new entries
 - Similar to spatial split BVH builders [Ganestam 2016, Fuetterling 2016]
- Distribute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



Parallelization

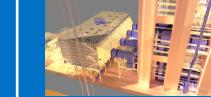
- Recusively spawn tasks when processing left and right sub-lists
- Parallize opening, binning, partition phases for lists with many entries
 - Can happen deep down in the BVH
- TBB good fit for exploiting nested parallelism
- Very good scalability in #threads

Results

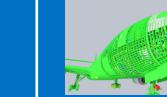


- Integrated our approach into Embree
- Path tracing for comparing rendering performance
- Dual-socket Intel Xeon E5-2699 v3 (36 cores total) with 64 GB of memory

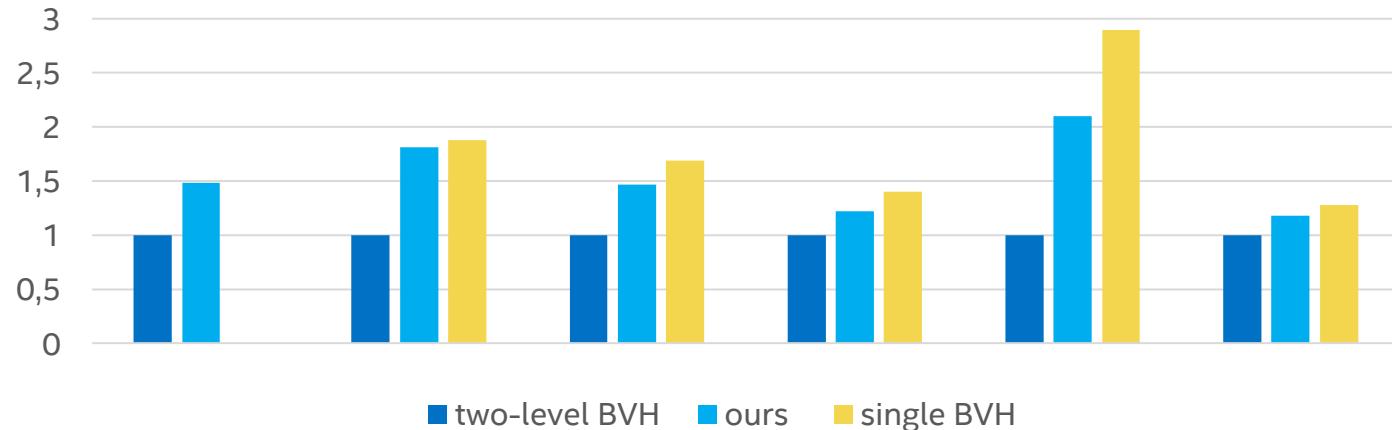
Rendering Performance

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

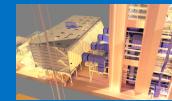
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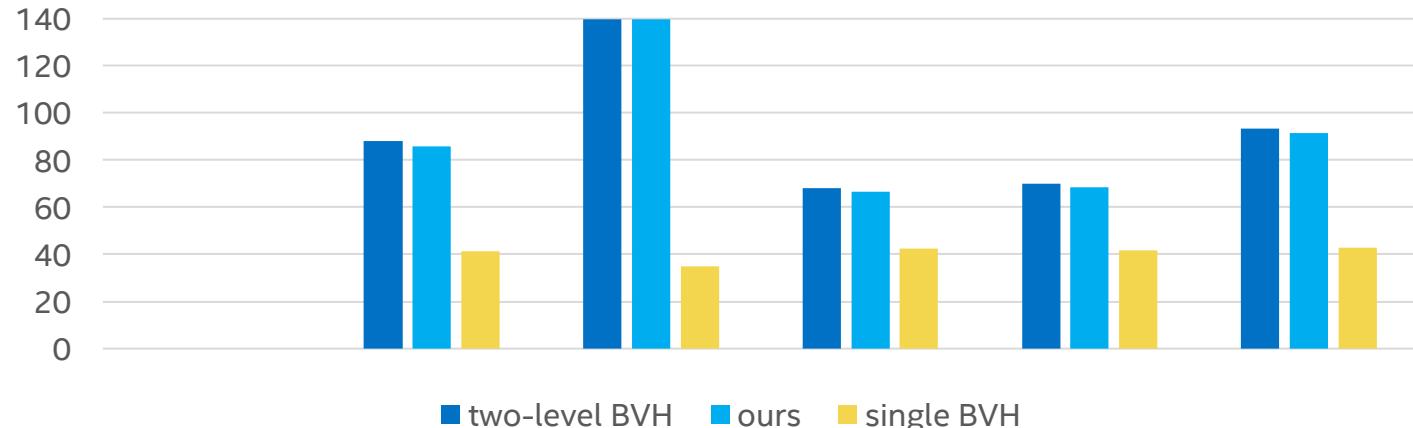
Relative Performance



BVH Build Performance

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

Million triangles / second



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

- Well fitted for partial scenes updates
 - Multiple large and complex static geometries
 - Few per frame changing dynamic geometries

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

Questions...

<https://embree.github.io>

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