Dual-Split Trees

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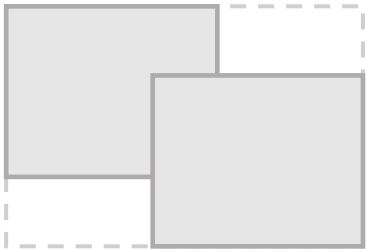
I3D 2019

Dual-Split Trees

- Identical space partitioning to BVHs
- Up to 48% less space
- Up to 30% higher performance

Motivation

- The two children of a BVH node have 12 planes, where 6 planes are always shared with the parent



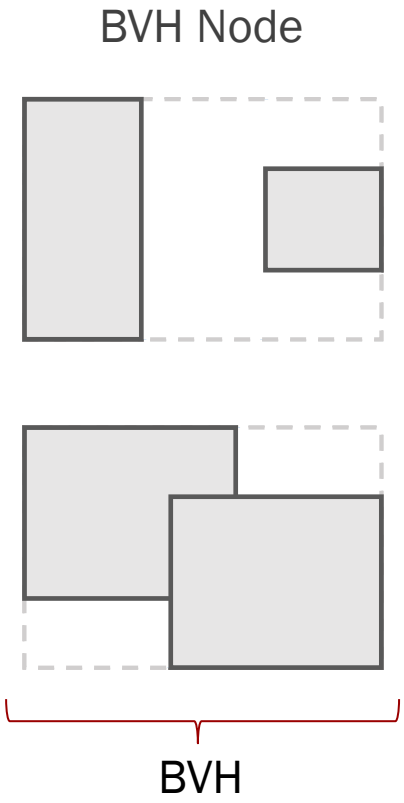
BVH

Motivation

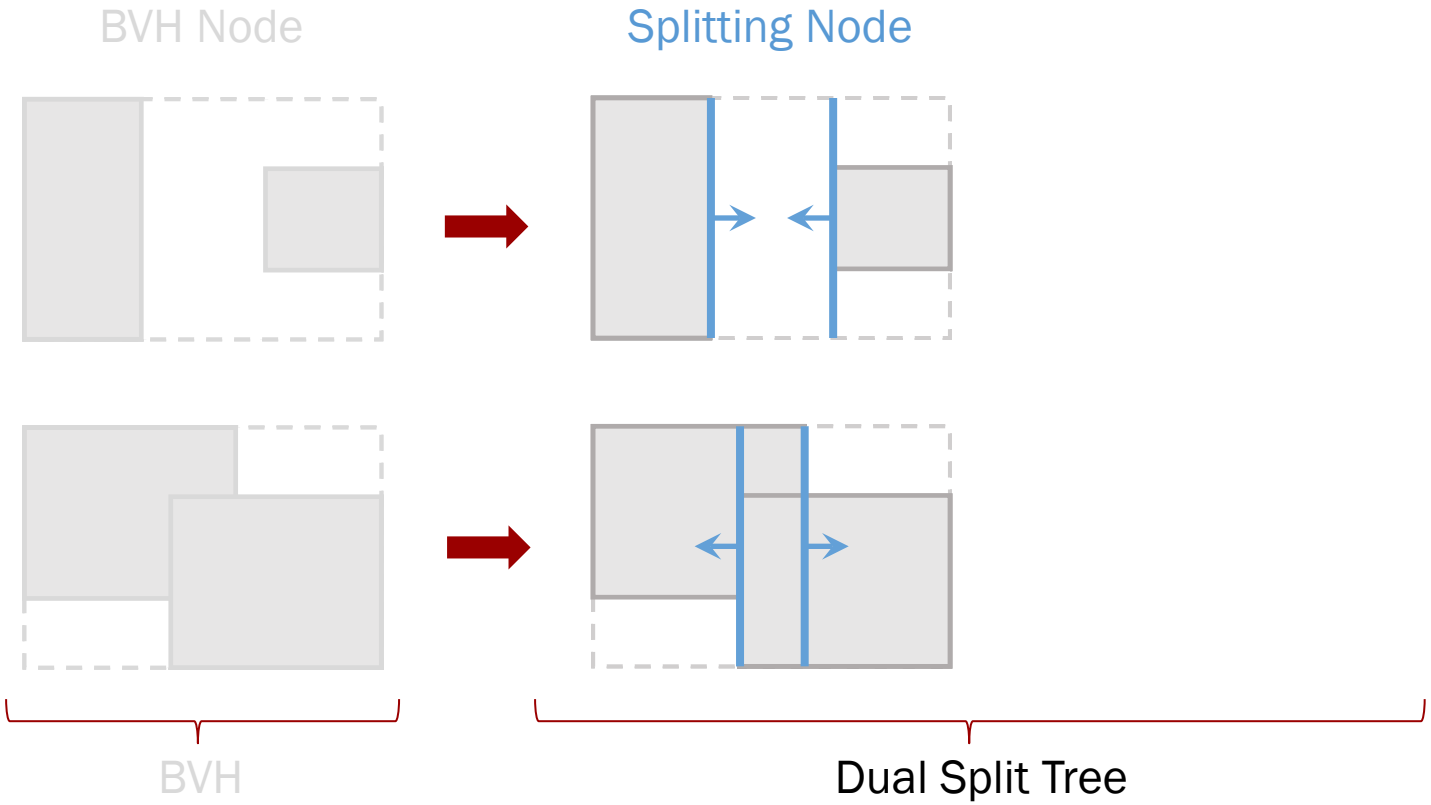
- The two children of a BVH node have 12 planes, where 6 planes are always shared with the parent

- Our solution
  - New acceleration structure
  - Hybrid BVH and kd-tree

BVH



Dual-Split Trees



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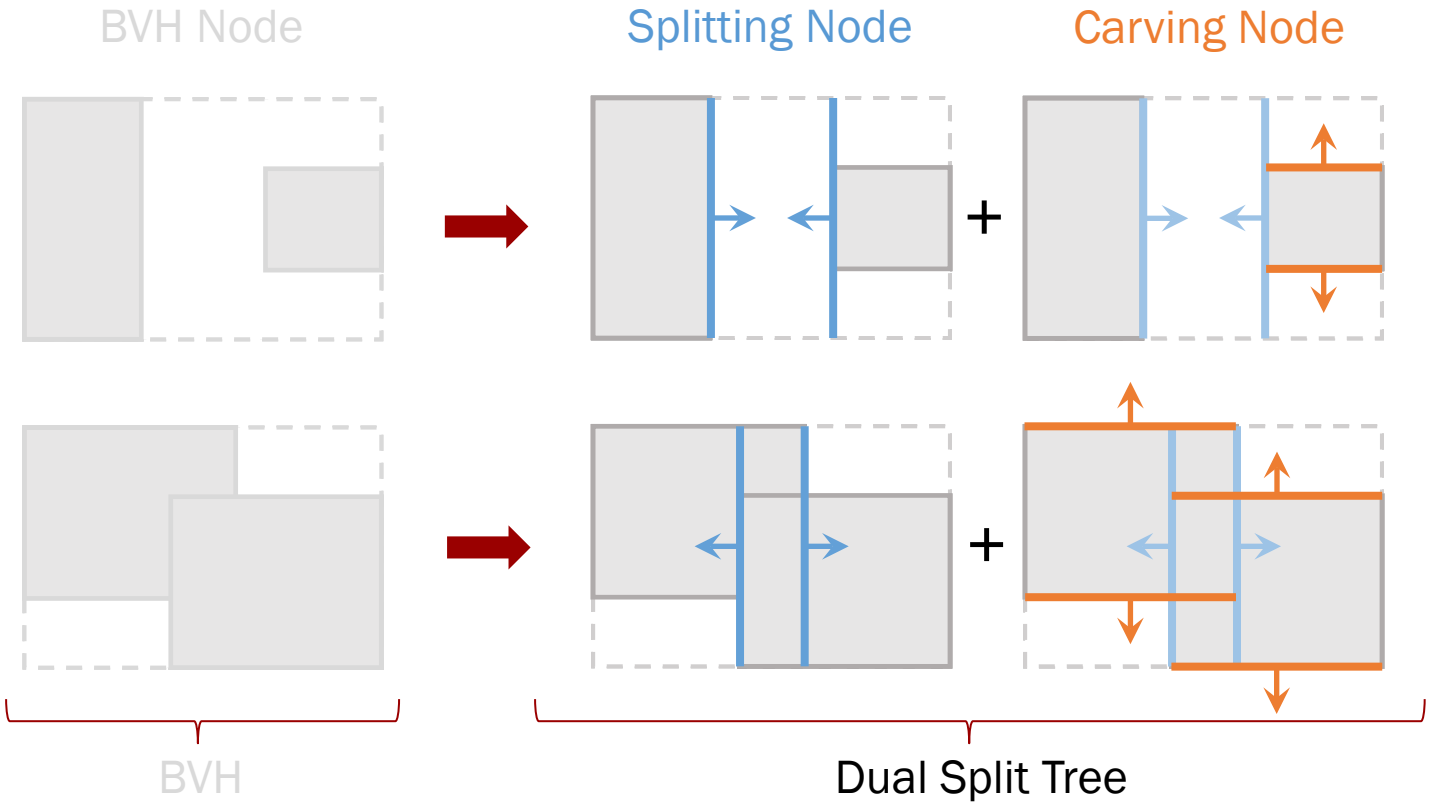
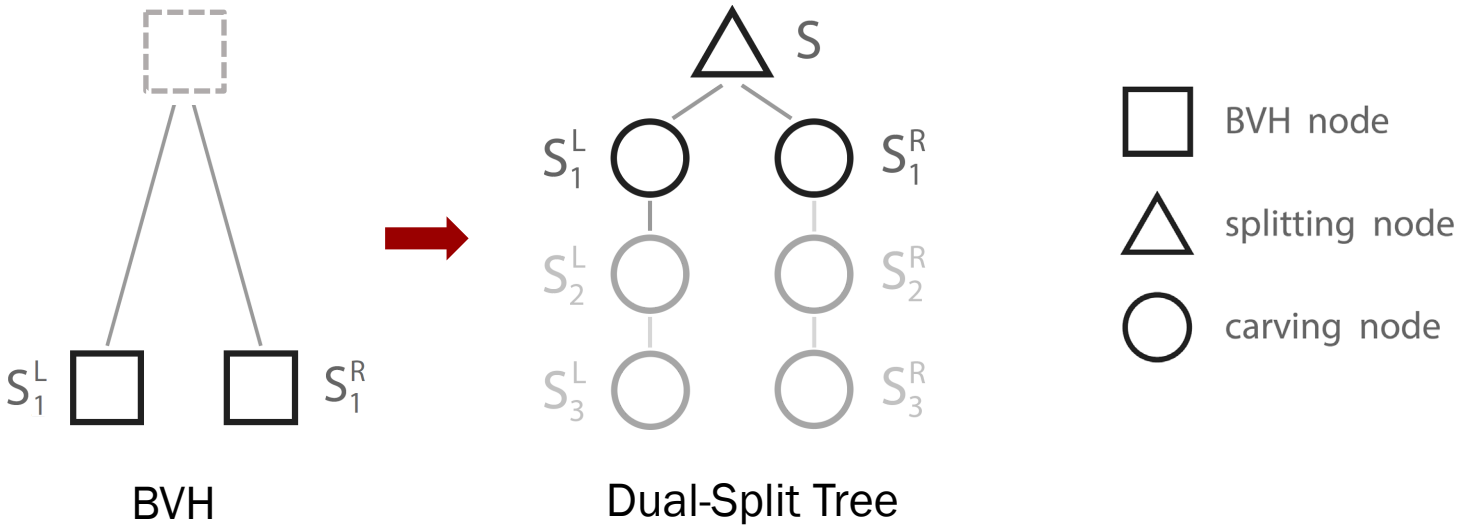


Tree Structure

- More nodes, less storage!



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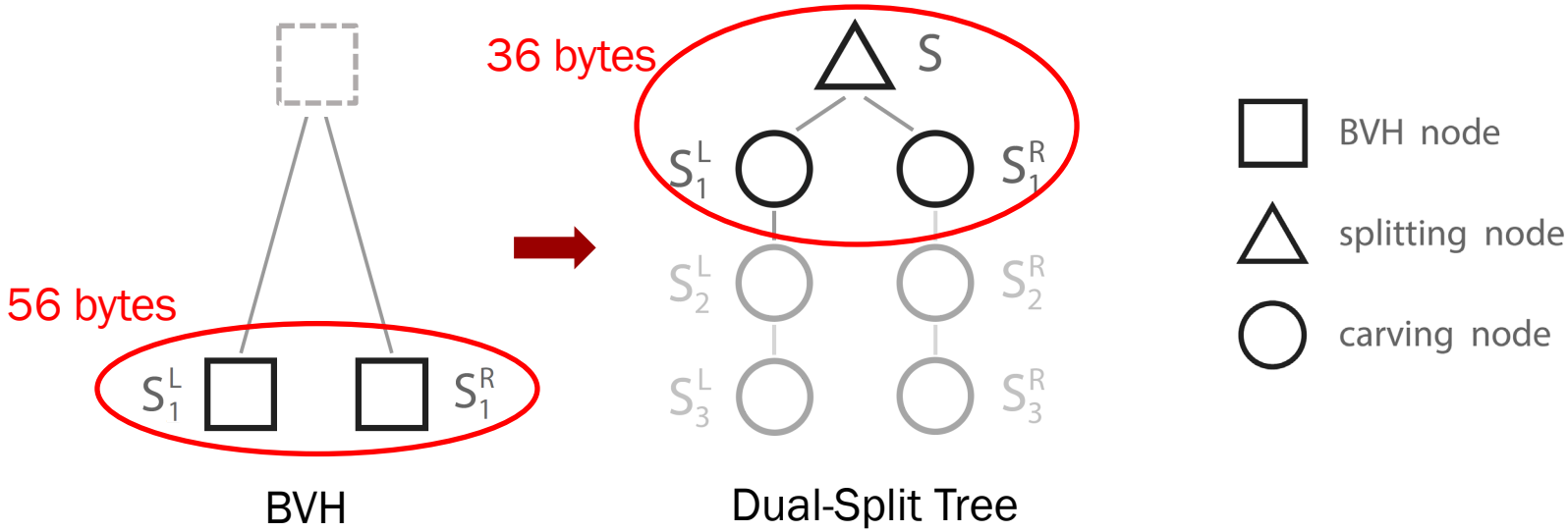
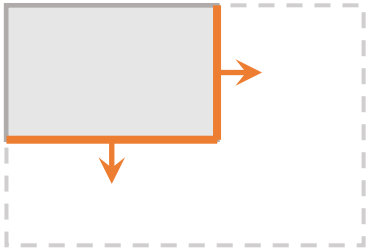
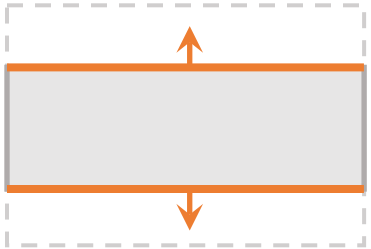


Dual-Split Trees

- Carving planes can also be perpendicular



Dual-axis Carving Node



Single-axis Carving Node

Dual-Split Trees

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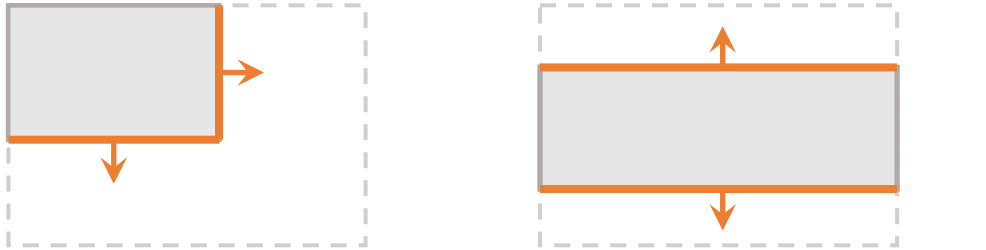


Dual-axis Carving Node Single-axis Carving Node

- Carving nodes can act as leaf nodes

Construction

- Directly build from the scene geometry

  or

- Convert from a BVH

Construction

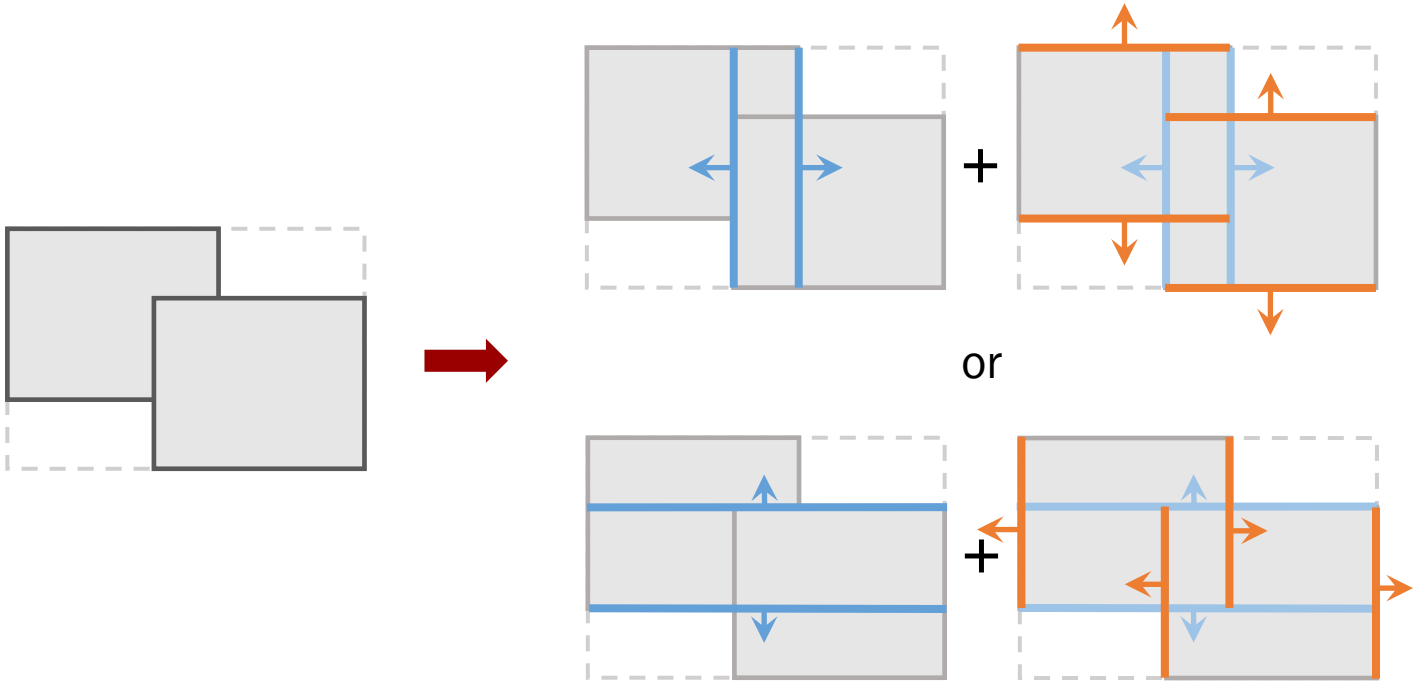
- Directly build from the scene geometry

  or

- Convert from a BVH

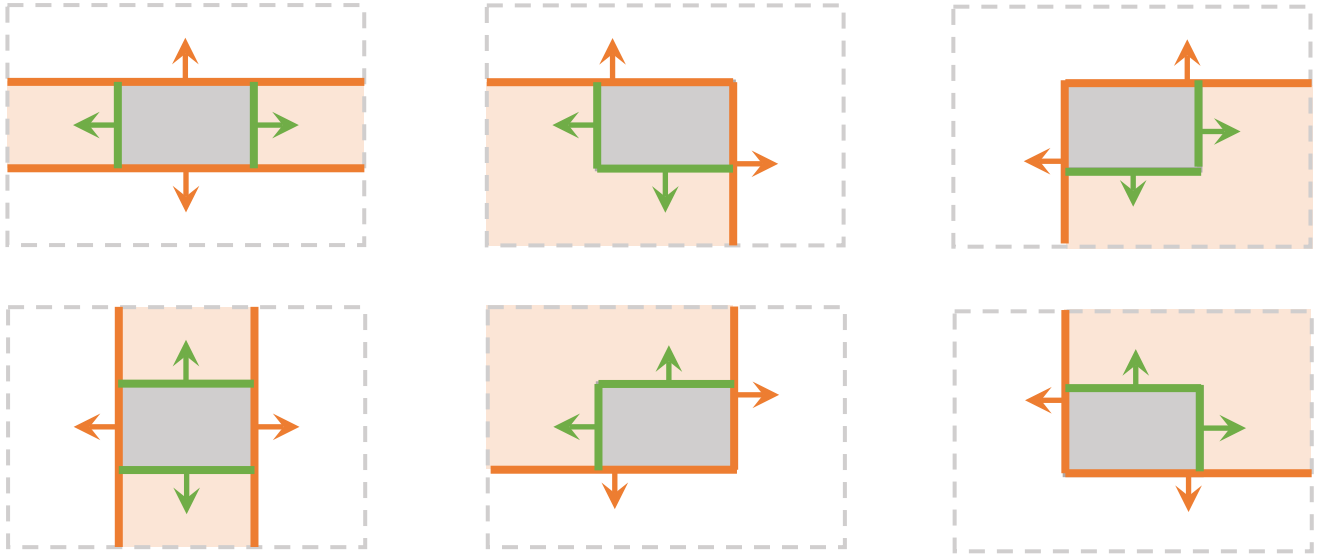
Construction from BVH

- Select axis that yields the lowest SAH cost



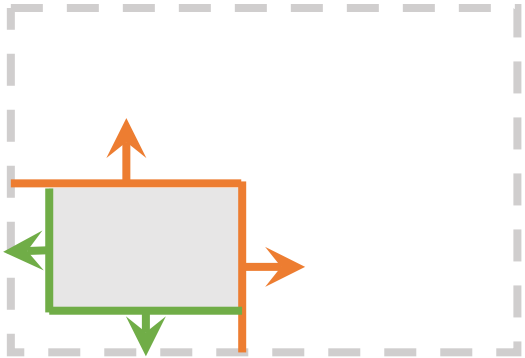
Construction from BVH

- Select carving node order/type that yields the lowest SAH cost

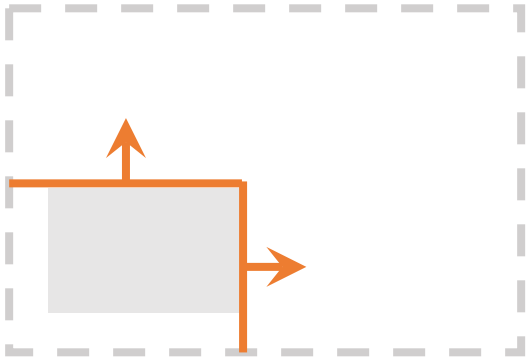


Construction from BVH

- Carving nodes with approximate bounds



Identical Bounds



Approximate Bounds

Construction from BVH

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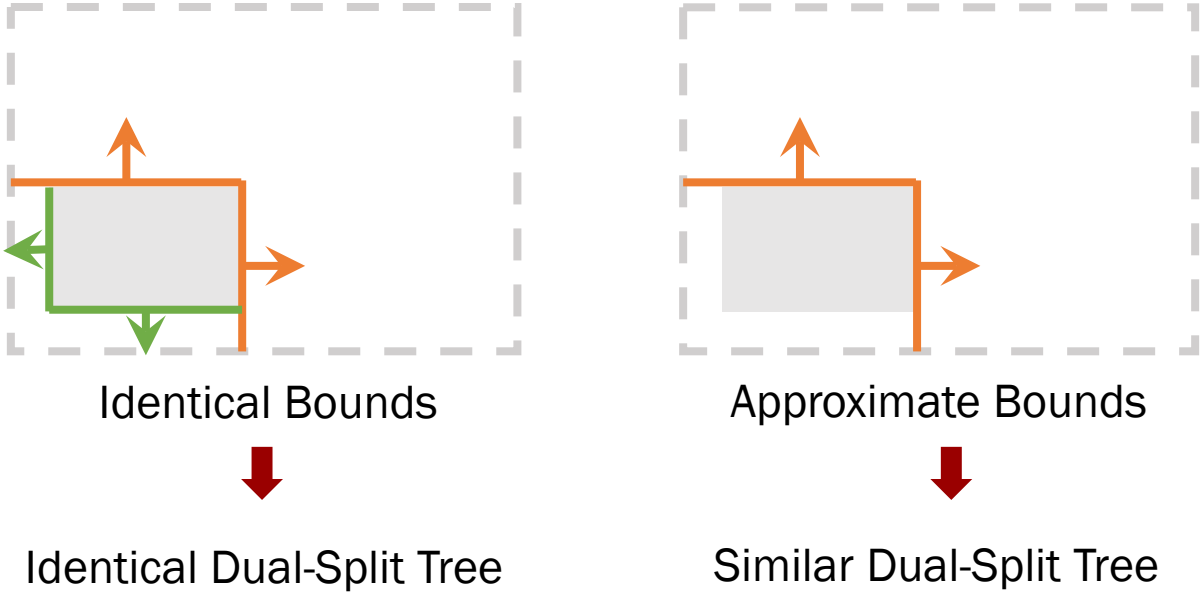
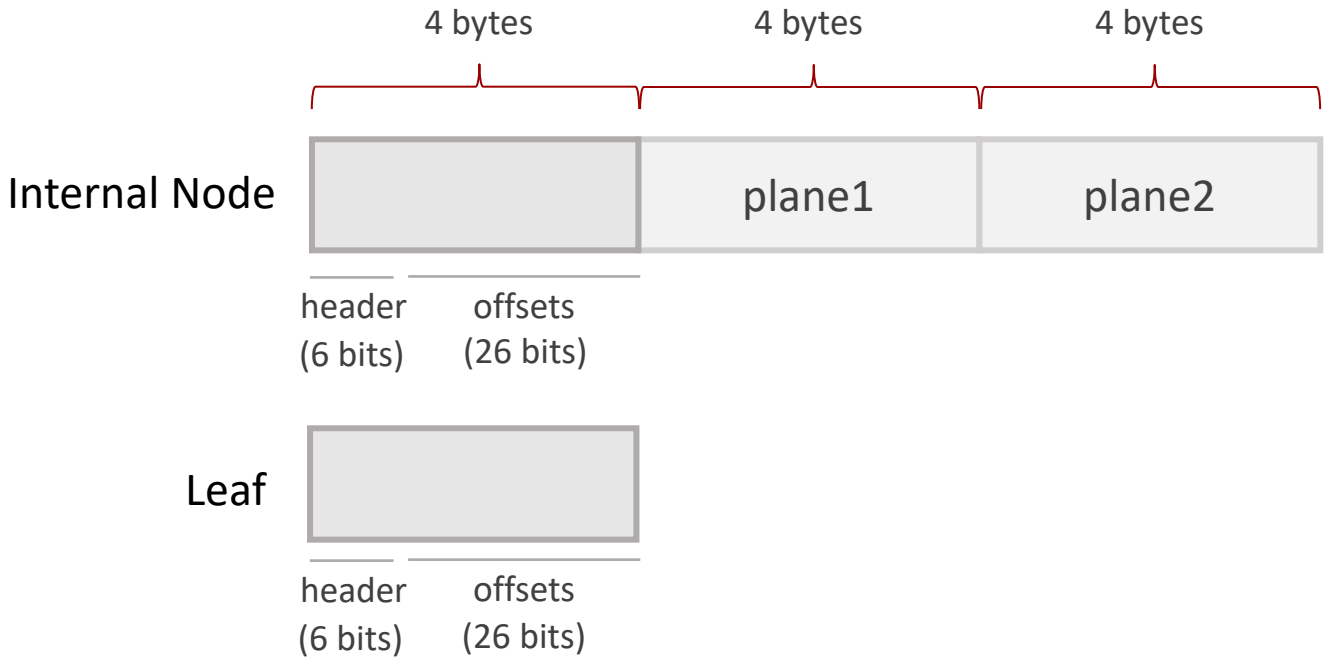


Node Structure



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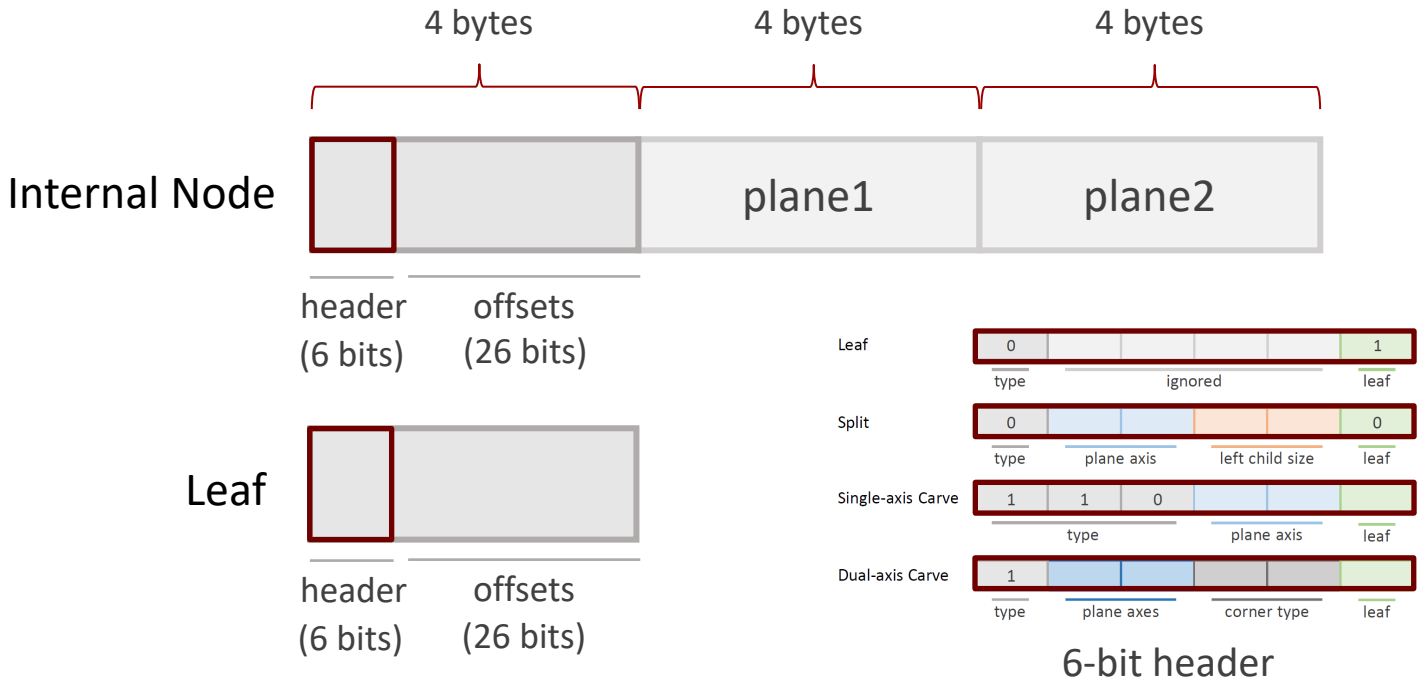


Traversal

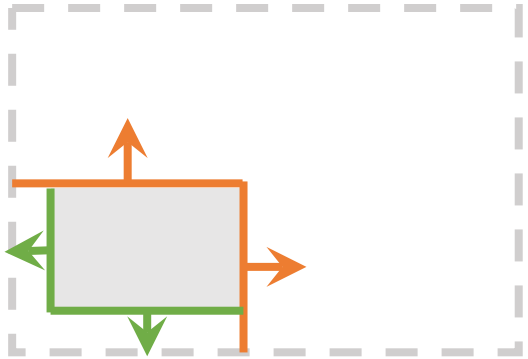
- Follows kd-tree order
- Additional case of passing through empty space

Evaluation method

- Compare with BVH and similar previous methods
- We use Embree to build the BVH
- Compare
  - space consumption
  - traversal speed

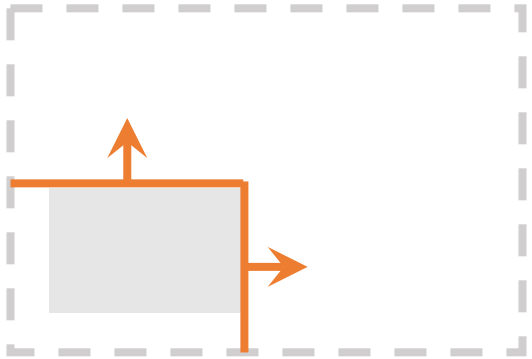
Evaluation method

- Additionally we include similar dual-split trees in our test



Identical Bounds

Identical Dual-Split Tree



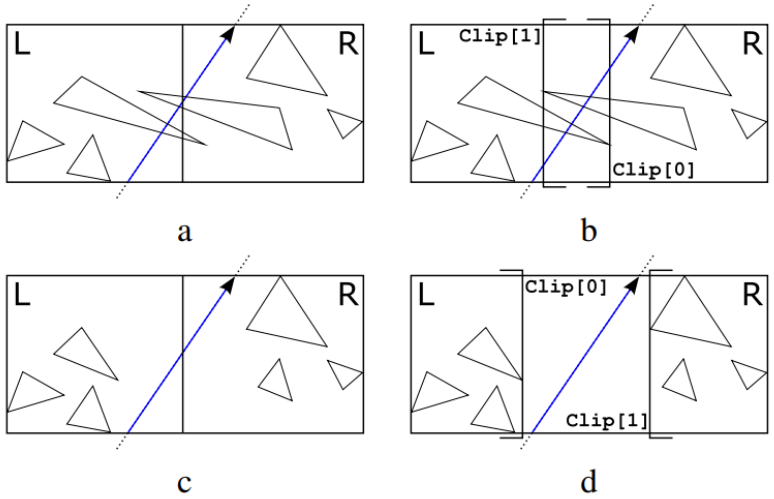
Approximate Bounds

Similar Dual-Split Tree

Similar Previous Methods

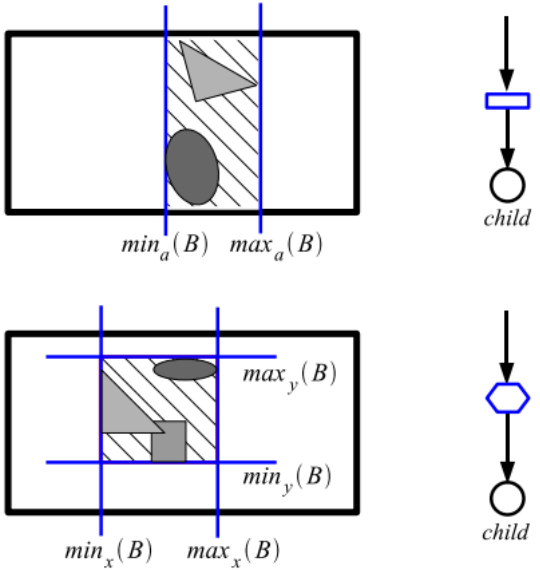
Similar Previous Methods

- BIH [Wächter & Keller et al., 2006]



Similar Previous Methods

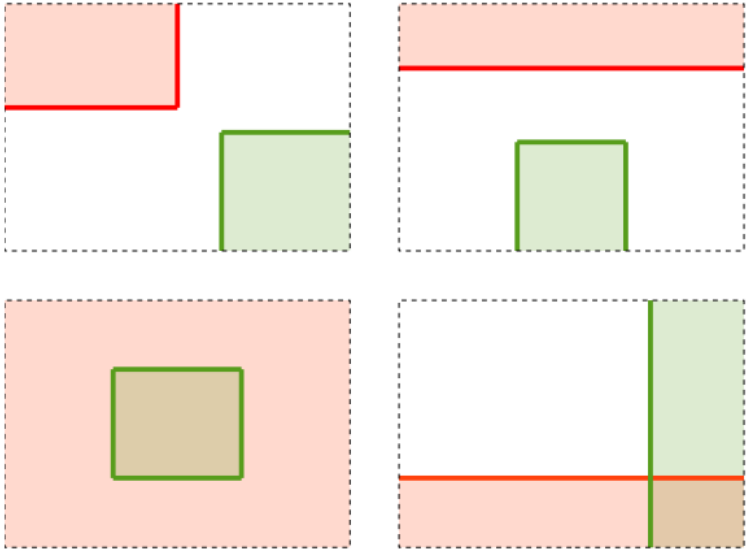
- BIH [Wächter & Keller et al., 2006]
- H-Tree [Havran et al., 2006]



Similar Previous Methods

- BIH [Wächter & Keller et al., 2006]
- H-Tree (Havran et al., 2006)
- Compact BVH

  [Fabianowski & Dingliana, 2009]



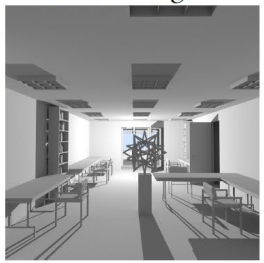
Test scenes

- Scenes are rendered by path tracing

Crytek Sponza
262K triangles

Vegetation
1.1M triangles

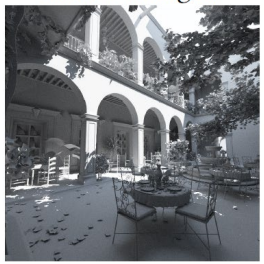
Sodahall Interior
2.2M triangles



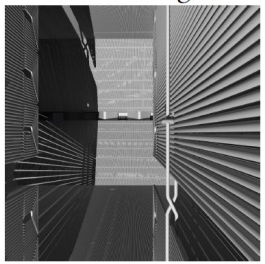
Hairball
2.9M triangles

Dragon Sponza
6.6M triangles

San Miguel
10.5M triangles



Powerplant
12.8M triangles



Results

- Space Consumption

Accel. Structure Storage (MB)	BVH	Dual-Split Trees (identical)	Dual-Split Trees (similar)	BIH	H-Tree	Compact BVH
Average	100%	62%	53%	87%	82%	57%
Crytek Sponza	7.04	4.53 (64%)	**3.59** (51%)	6.55 (93%)	6.13 (87%)	4.02 (57%)
Vegetation	22.7	15.7 (69%)	13.8 (61%)	23.9 (105%)	21.8 (96%)	**13.0** (57%)
Soda Hall Interior	51.9	28.7 (55%)	**25.6** (49%)	37.2 (72%)	36.3 (70%)	29.7 (57%)
Hairball	43.8	28.7 (66%)	**22.9** (52%)	41.5 (95%)	37.7 (86%)	25.0 (57%)
Dragon Sponza	182	112 (61%)	**98.2** (54%)	148 (81%)	147 (81%)	104 (57%)
San Miguel	266	174 (66%)	**145** (55%)	259 (97%)	242 (91%)	152 (57%)
Powerplant	316	164 (52%)	**147** (47%)	213 (67%)	207 (65%)	180 (57%)

(Values shown in red are the smallest in the comparison)

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Avg. Frame Time (sec)	Crytek Sponza	2.65	**2.04** (77%)	**2.04** (77%)	2.36 (89%)	2.35 (88%)	2.83 (107%)
	Vegetation	2.58	**2.35** (91%)	**2.34** (91%)	2.71 (105%)	2.66 (103%)	2.94 (114%)
	Soda Hall Interior	3.21	**2.64** (82%)	2.65 (83%)	2.85 (89%)	2.76 (86%)	3.31 (103%)
	Hairball	1.70	1.57 (92%)	**1.53** (90%)	1.78 (104%)	1.72 (101%)	1.93 (113%)
	Dragon Sponza	2.31	**1.92** (83%)	1.95 (84%)	2.06 (89%)	2.20 (95%)	2.41 (104%)
	San Miguel	3.62	3.21 (89%)	**3.20** (88%)	3.71 (102%)	3.62 (100%)	4.03 (111%)
	Powerplant	7.21	**6.21** (86%)	**6.19** (86%)	7.21 (100%)	7.17 (99%)	7.93 (110%)

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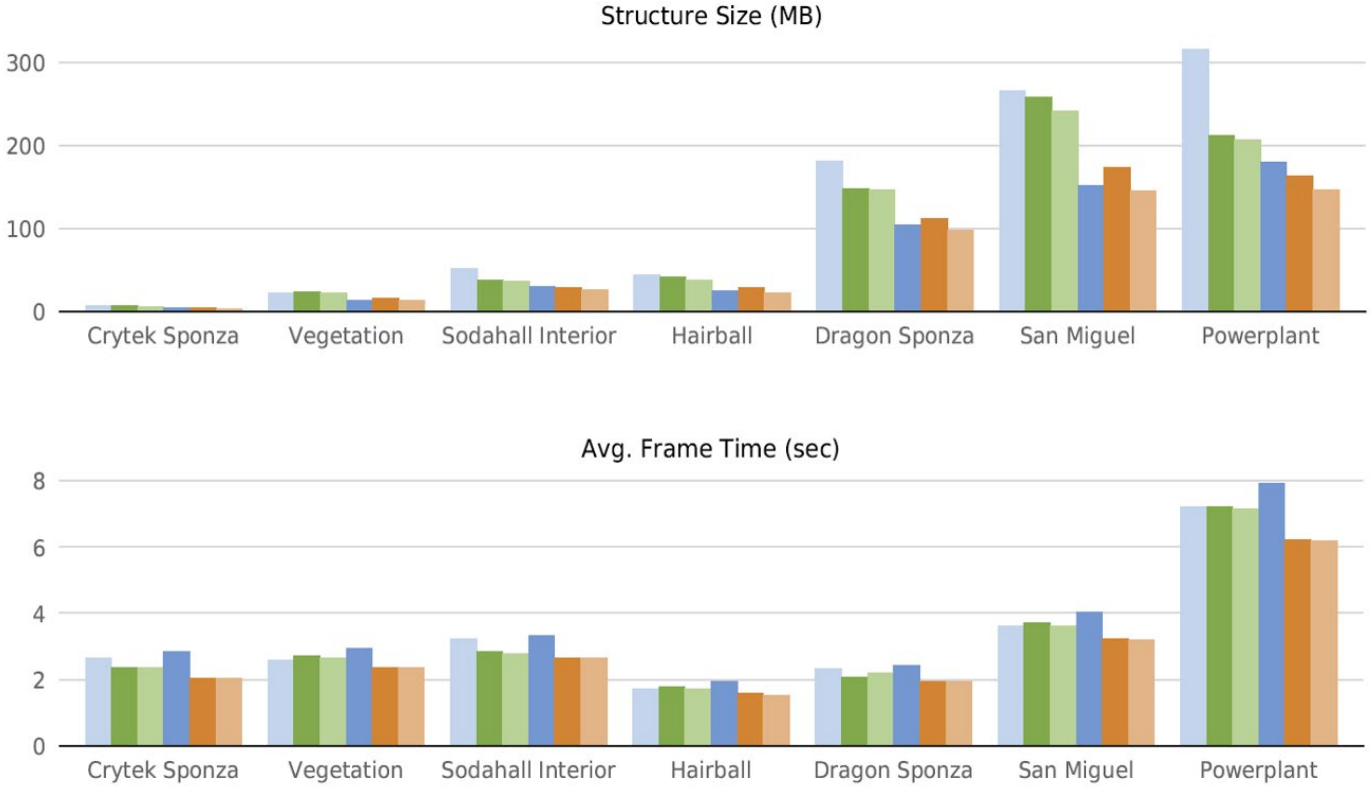
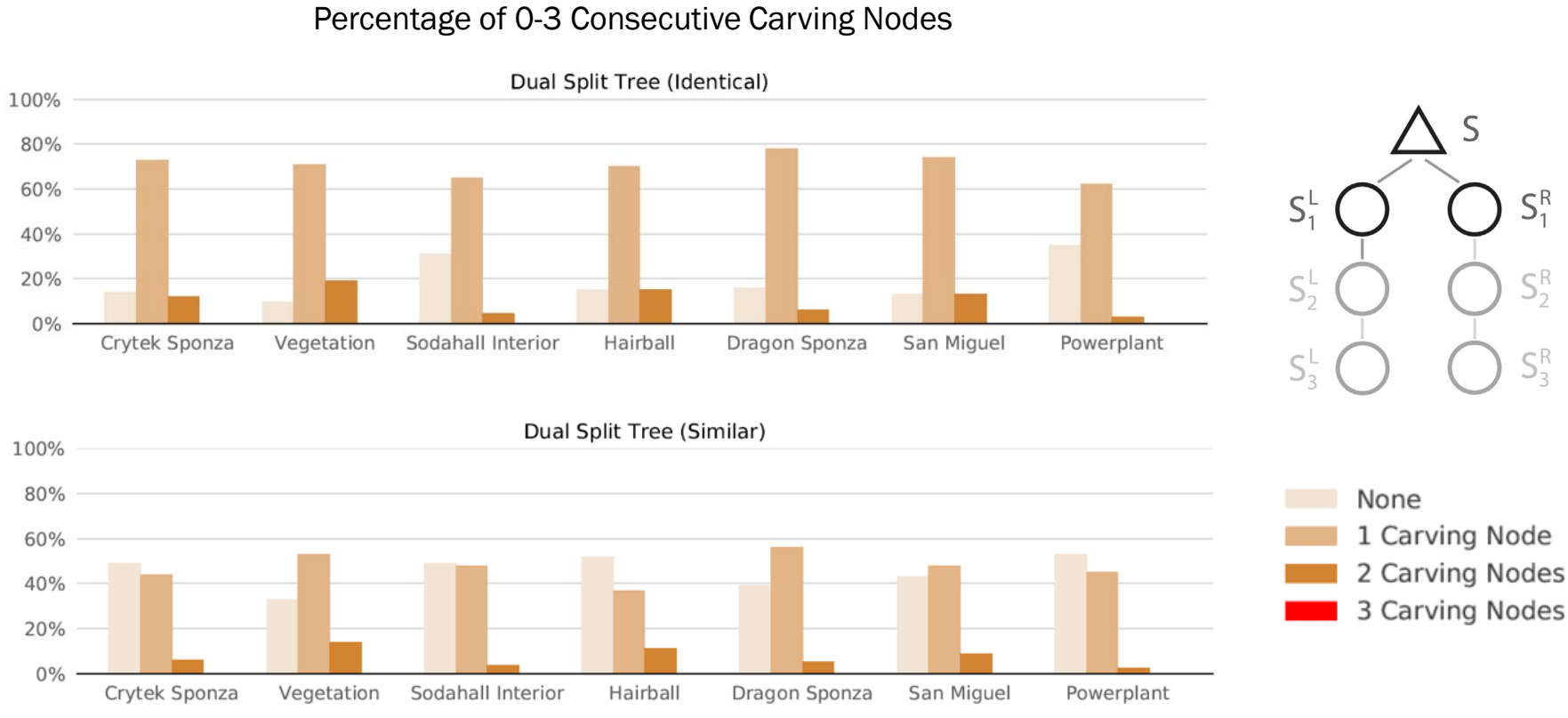

Structure Size (MB)
300
200
100
0
Crytek Sponza
Vegetation
Sodahall Interior
Hairball
Dragon Sponza
San Miguel
Powerplant
Avg. Frame Time (sec)
8
6
4
2
0
Crytek Sponza
Vegetation
Sodahall Interior
Hairball
Dragon Sponza
San Miguel
Powerplant
BVH
BIH
H-Tree
Compact BVH
Dual-Split Tree (identical)
Dual-Split Tree (similar)

Additional Analysis



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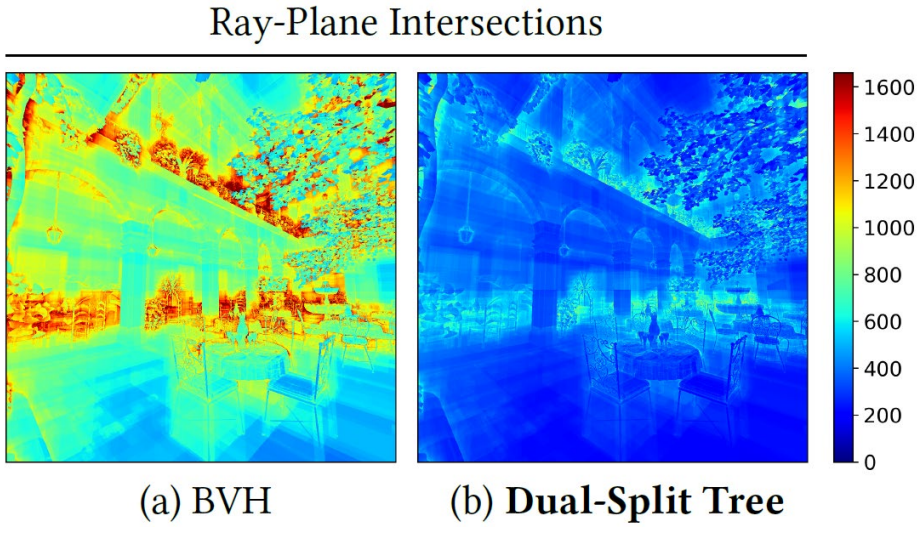
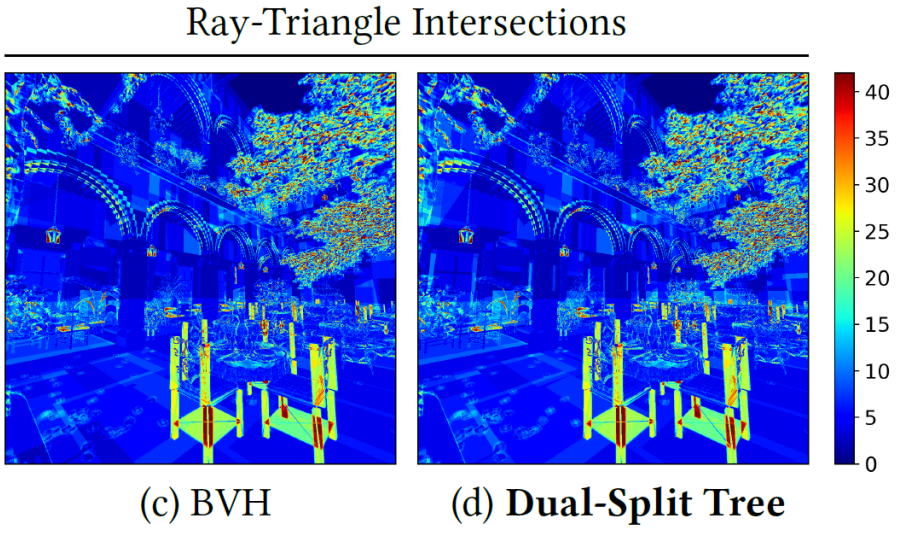


(a) BVH (b) **Dual-Split Tree**



(c) BVH (d) **Dual-Split Tree**

Additional Analysis

- Nodes Traversed per Ray
  - BVH: 100%
  - **Dual-split tree (identical): 209%**
  - **Dual-split tree (similar): 206%**
  - BIH: 257%
  - H-Tree: 188%
  - Compact BVH: 100%

Conclusion

- We introduce dual split trees
  - can be easily converted from any BVHs
  - substantial space savings
  - performance improvement

Thank you

- Project page

  https://dqlin.xyz/pubs/2019-i3d-DST/

Dual-Split Trees

I3D 2019