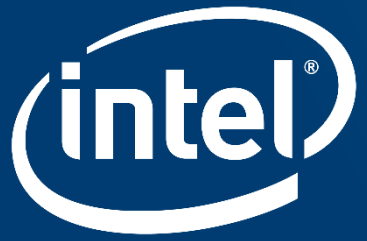


Wide BVH traversal with a short stack

Karthik Vaidyanathan, Sven Woop, Carsten Benthin

Motivation

Ray tracing hardware acceleration easily constrained by memory bandwidth

- Compressed wide BVHs can reduce node bandwidth
  [Wald et al. 14, Ylitie et al. 17]
- Lossless meshlet compression can reduce geometry bandwidth
- Full stack can add additional bandwidth when stored to memory when procedural geometry is intersected

➔ Need stack algorithm for wide BVHs with compact state

Previous Work

Stackless traversal with skip pointers [Smits 98]

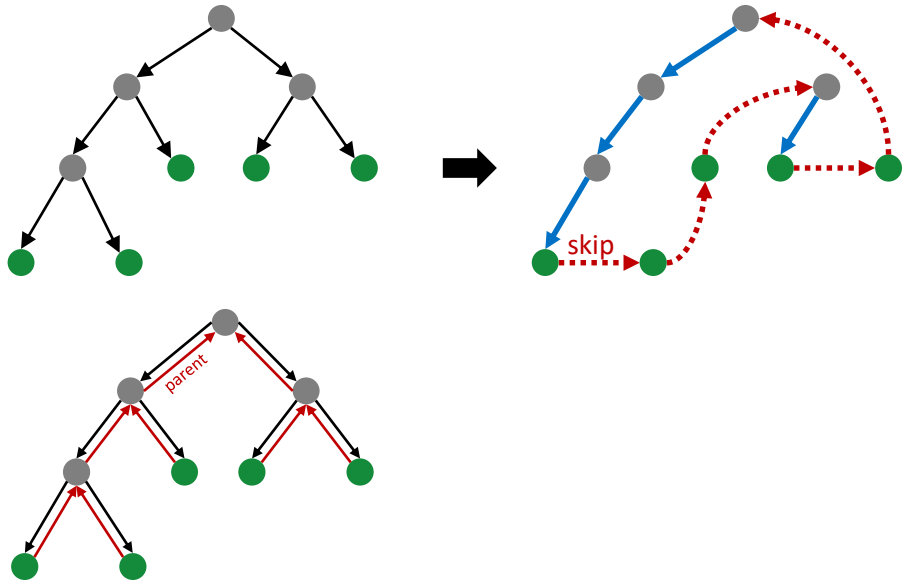
- Enforces a fixed traversal order

Stackless traversal with backtracking to parent
[Hapala et al. 11, Afra et al. 14]

- Allows front to back order
- Needs to re-intersect parent node

Binary BVH traversal with a restart trail [Laine 10]

- Maintain a restart trail and short stack of topmost entries
- Restart from root on an short stack underflow



BVH Traversal with a Restart Trail

A restart trail with short stack is well suited for fixed function ray tracing

- Short stack entries and the restart trail small
- Low overhead (10%) as short stack avoids most redundant traversal steps

Our Wide-BVHs restart trail algorithm builds on
binary BVH traversal of [Laine 10]

Binary BVH Traversal with a Restart Trail

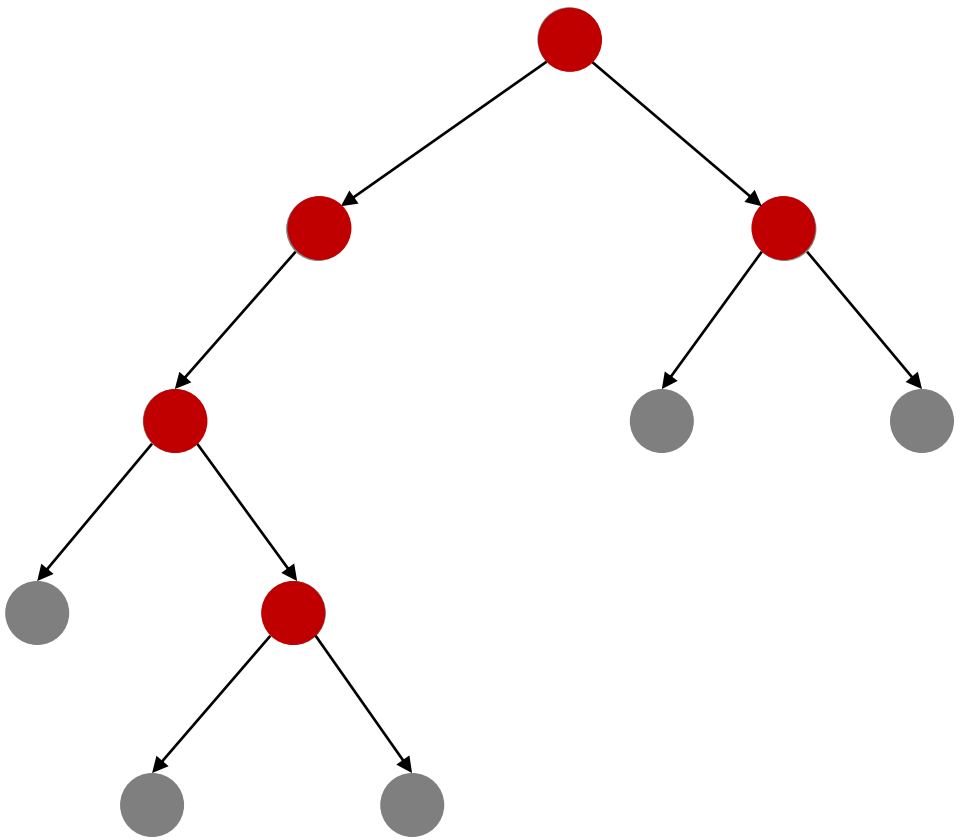
Assuming fixed front to back ordering of child nodes along the ray

Restart trail is bit vector (and depth) that encodes processed part of BVH

- RestartTrail[level] == 0 indicates that the **first child** is being traversed
- RestartTrail[level] == 1 indicates that the **last child** at the given *level* is being traversed

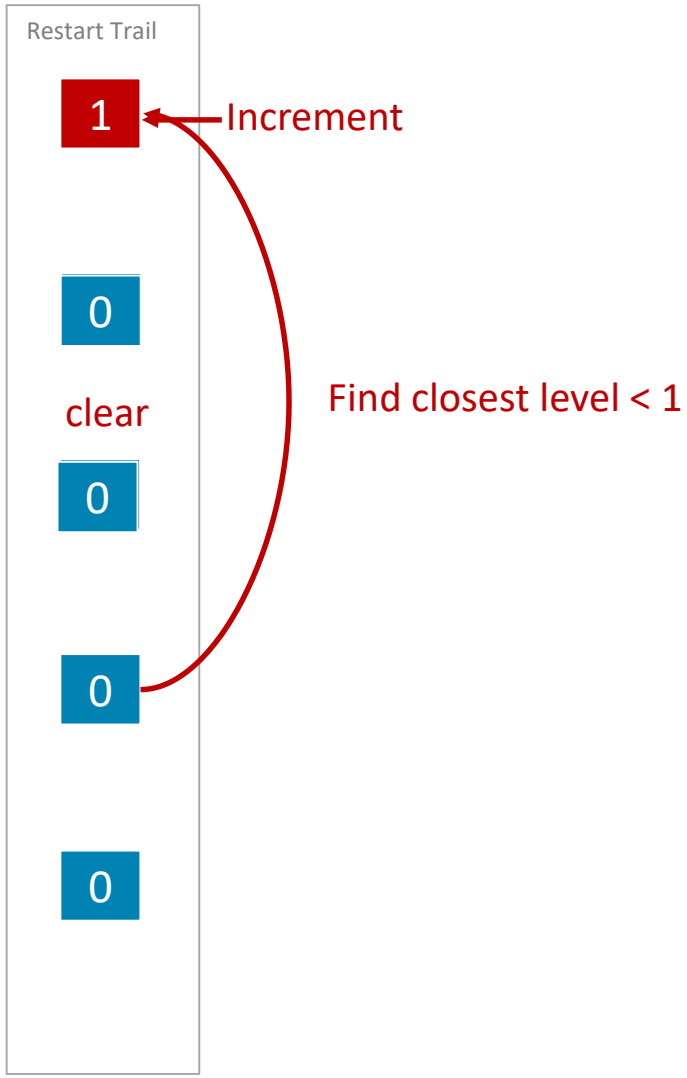
➔ Pop operations can easily skip over finished levels

Binary Restart Trail



LEVEL = 1

LEVEL = 3



N-Wide BVH Traversal with a Restart Trail

Assuming fixed front to back ordering of child nodes along the ray

Restart trail is an **integer vector** (and depth) that encodes processed part of BVH

- RestartTrail[level] indicates the n’th child currently traversed
- RestartTrail[level] set to N-1 indicates the last child subtree being traversed

➔ Pop operations can easily skip over finished levels

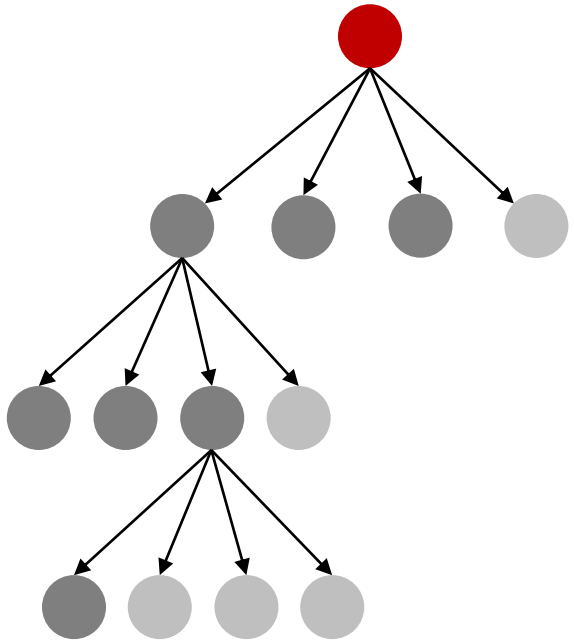
Detecting the Last Child

During down traversal the last child at a given level is detected when RestartTrail[level] == (number of intersections – 1)

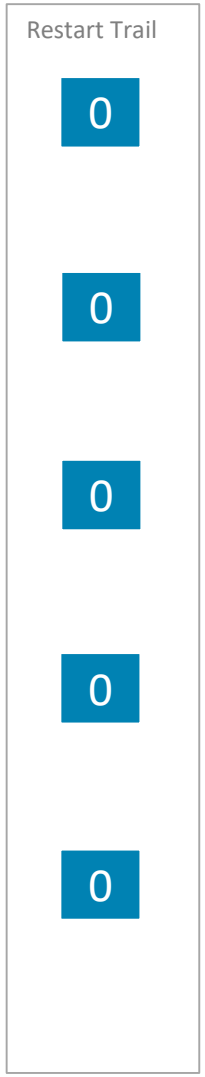
But we do not know if an entry popped from the short stack is the last child

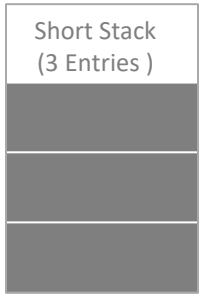
- Therefore we use **one additional bit** per short stack entry to mark the last child when it is pushed onto the stack.
- Not required for binary BVH as popped nodes are always the last node.

Example 4-Wide BVH Traversal

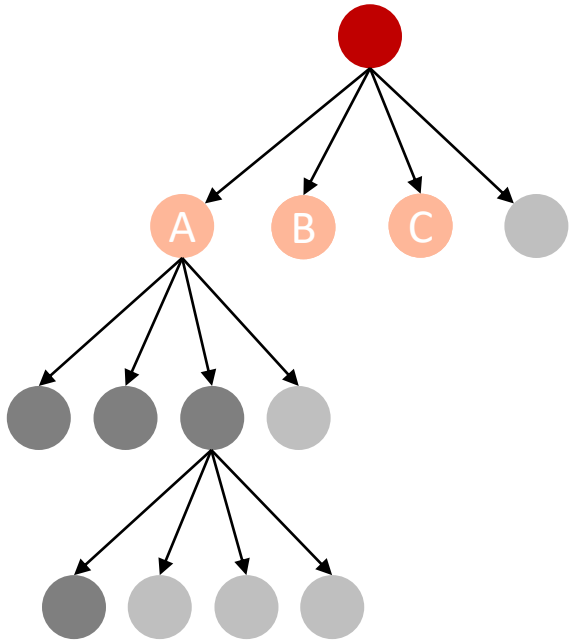


LEVEL = 0

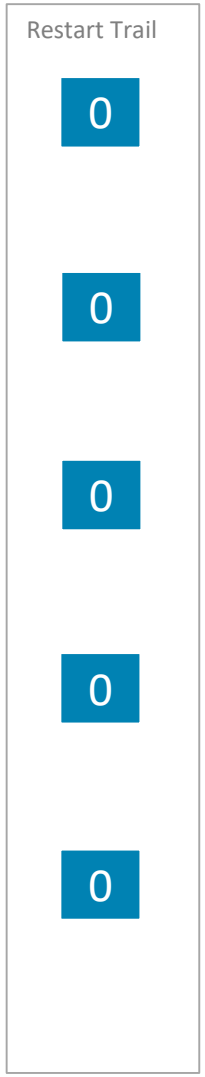


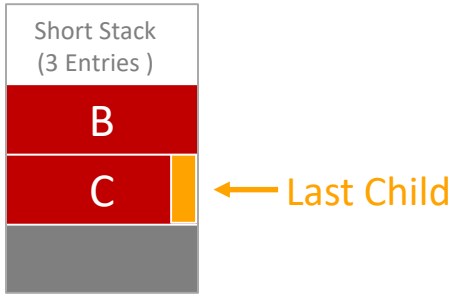


Example 4-Wide BVH Traversal

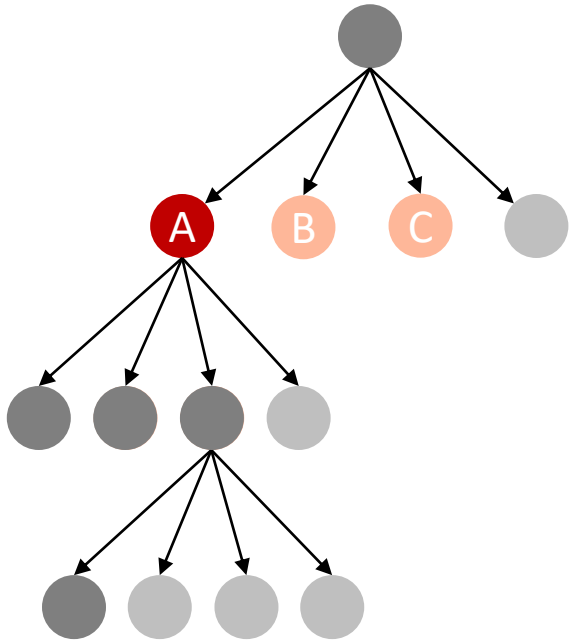


LEVEL = 0

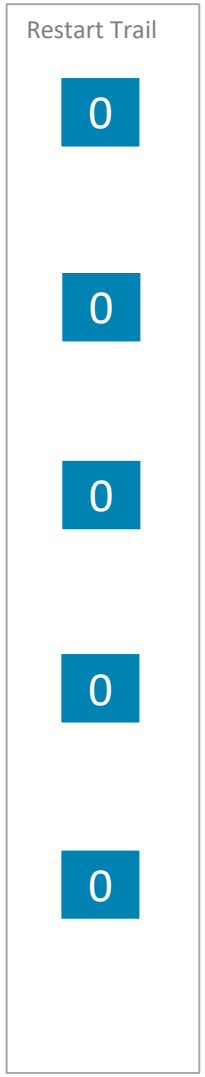


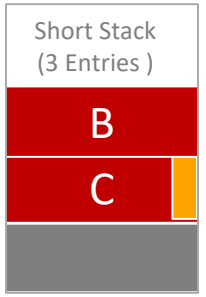


Example 4-Wide BVH Traversal

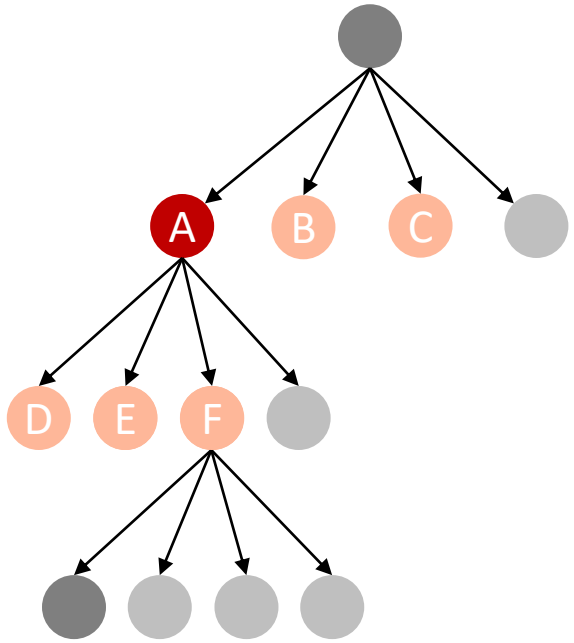


LEVEL = 1

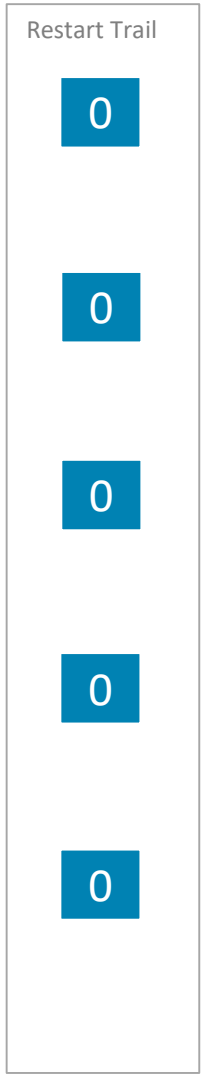


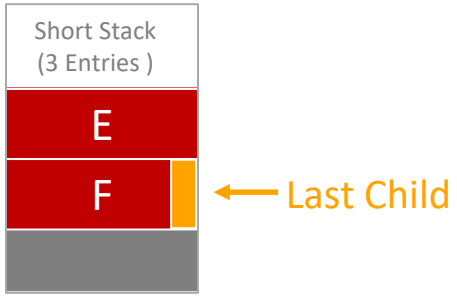


Example 4-Wide BVH Traversal



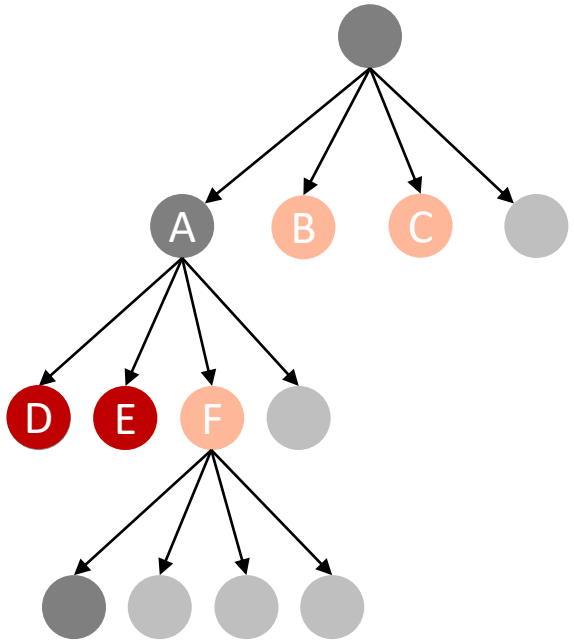
LEVEL = 1





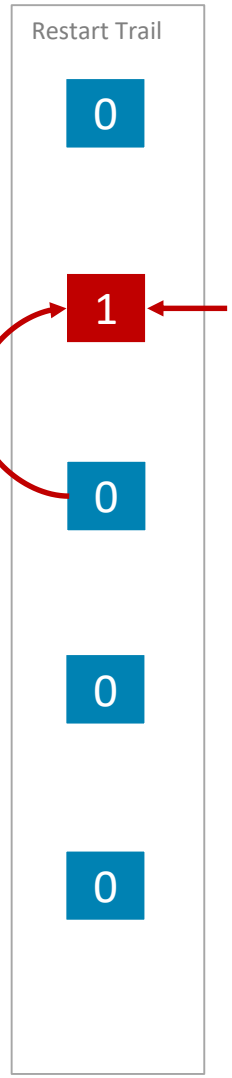
C dropped

Example 4-Wide BVH Traversal

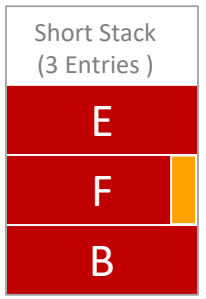


Find closest level < 3

LEVEL = 2

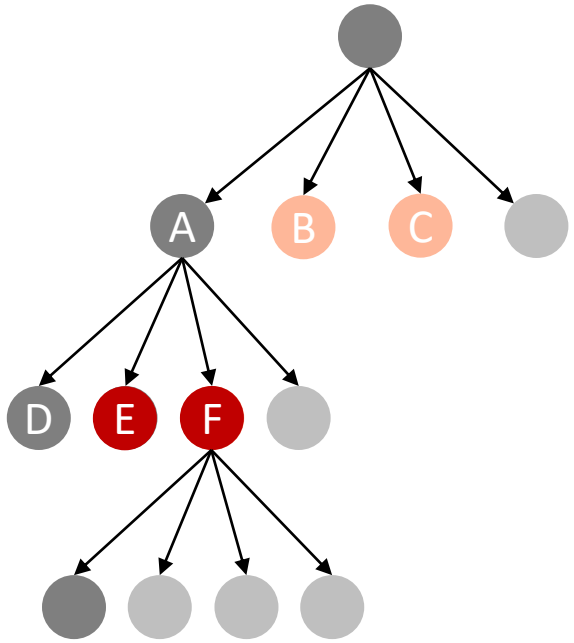


Increment



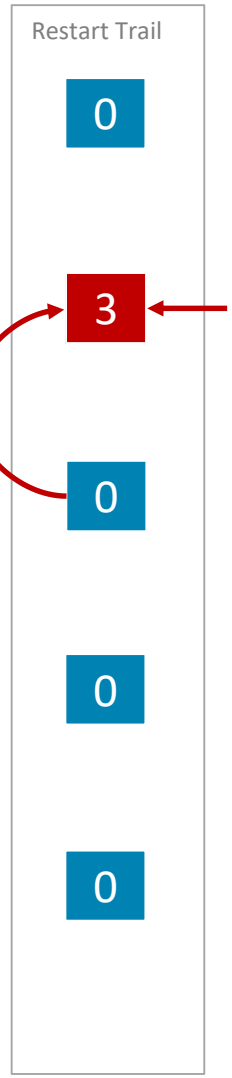
E Popped

Example 4-Wide BVH Traversal

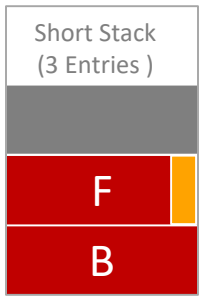


Find closest level < 3

LEVEL = 2

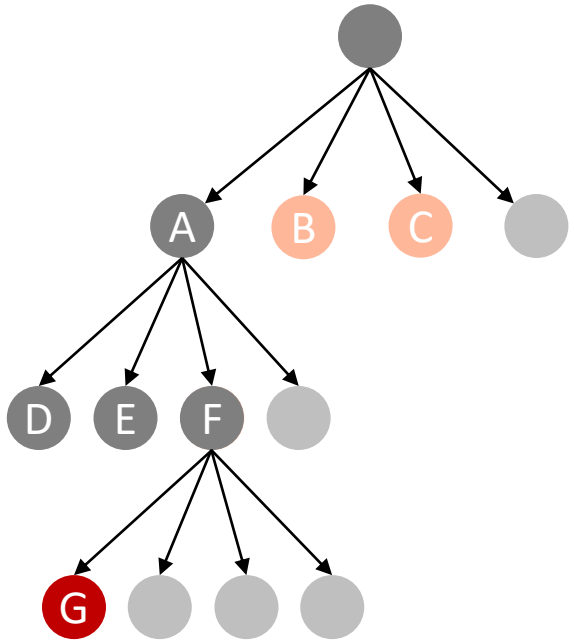


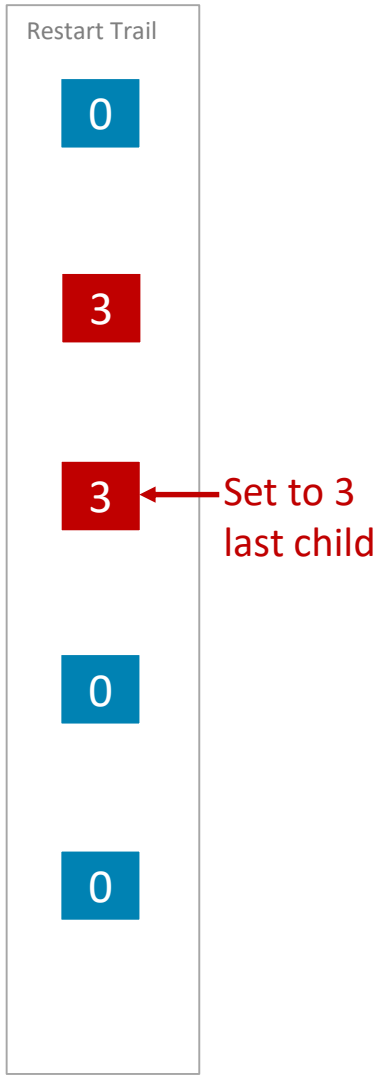
Set to 3
last child



F Popped

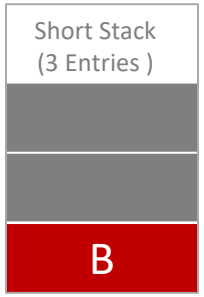
Example 4-Wide BVH Traversal



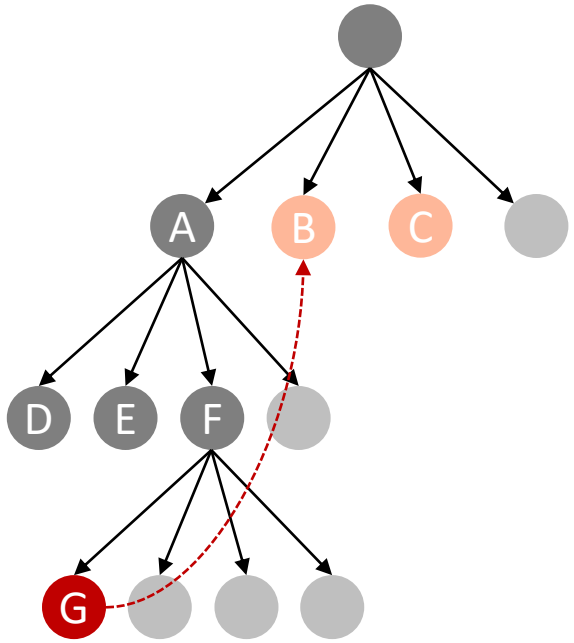


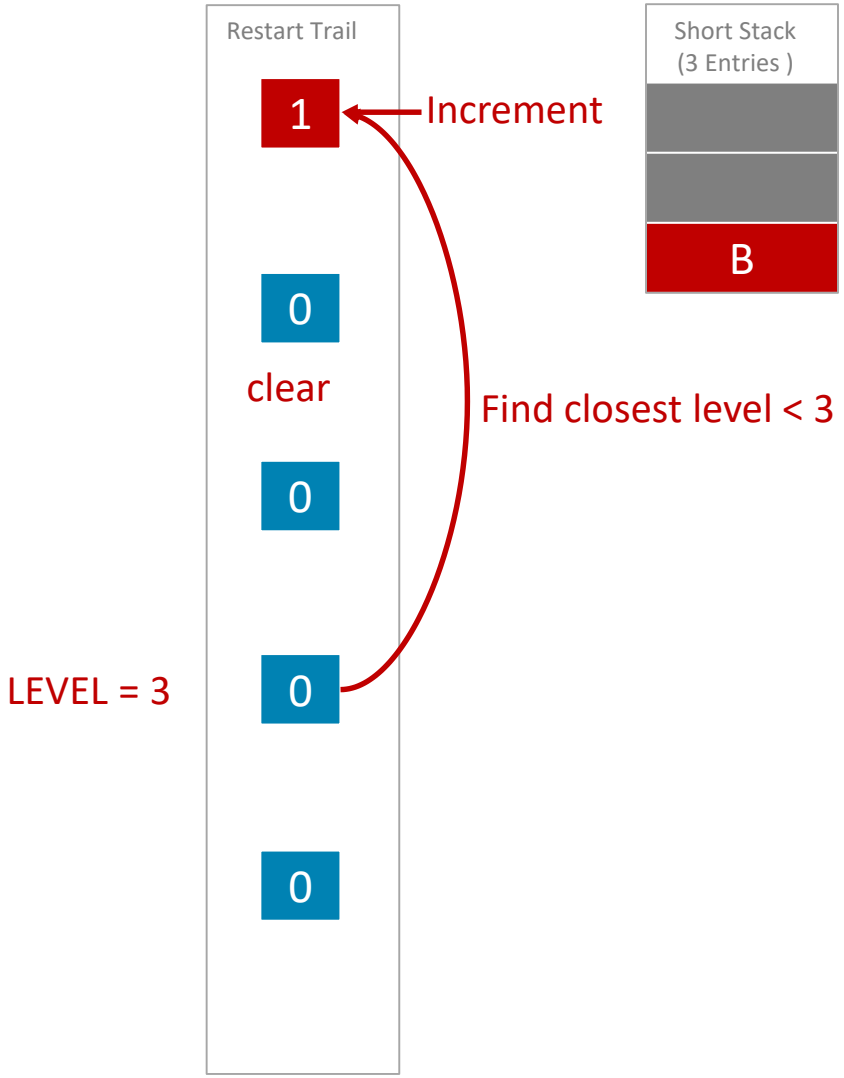
Set to 3
last child

LEVEL = 3

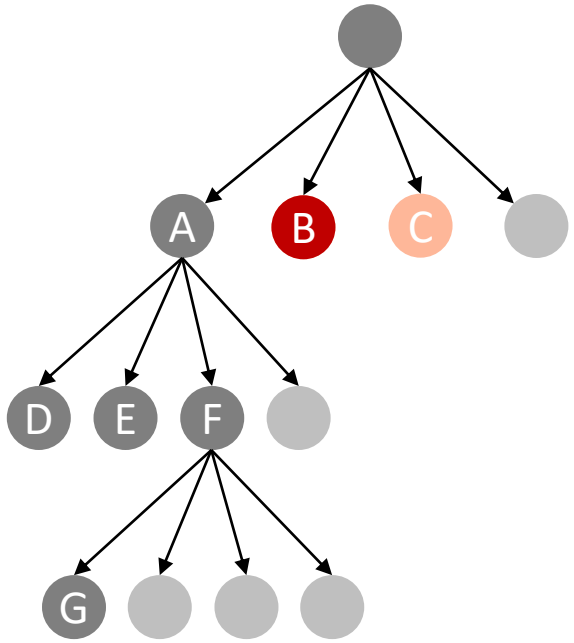


Example 4-Wide BVH Traversal



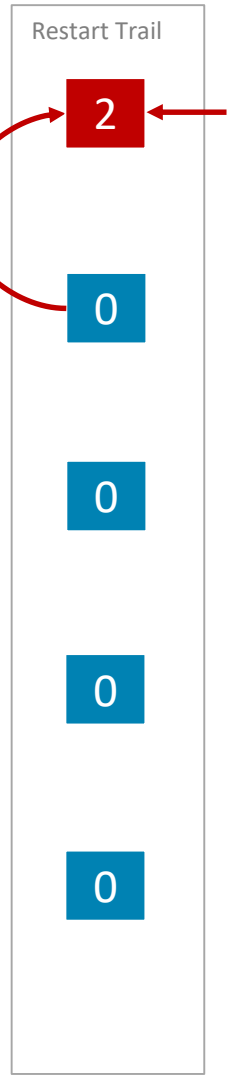


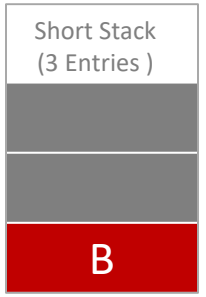
Example 4-Wide BVH Traversal



Find closest level < 3

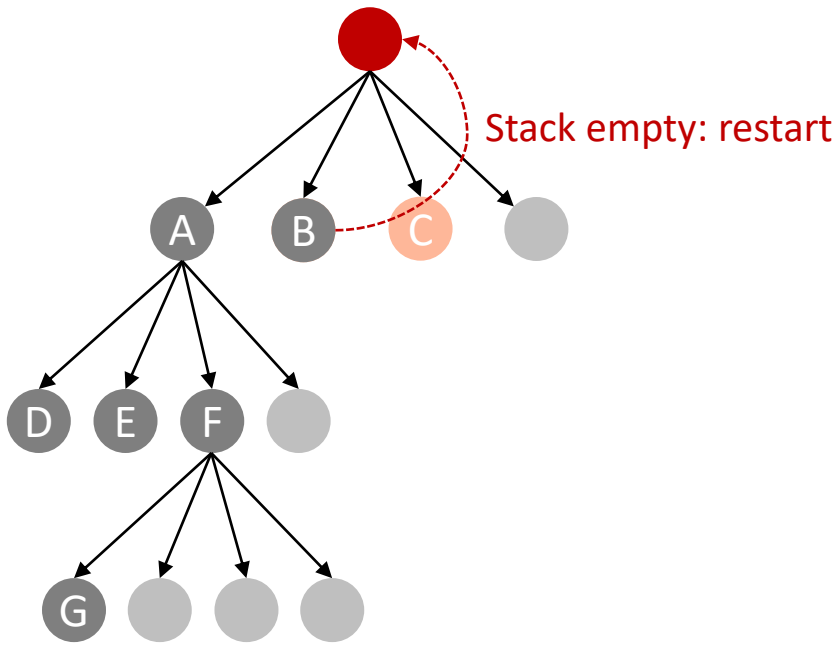
LEVEL = 1





B Popped

Example 4-Wide BVH Traversal



Stack empty: restart

LEVEL = 0

Restart Trail

2

0

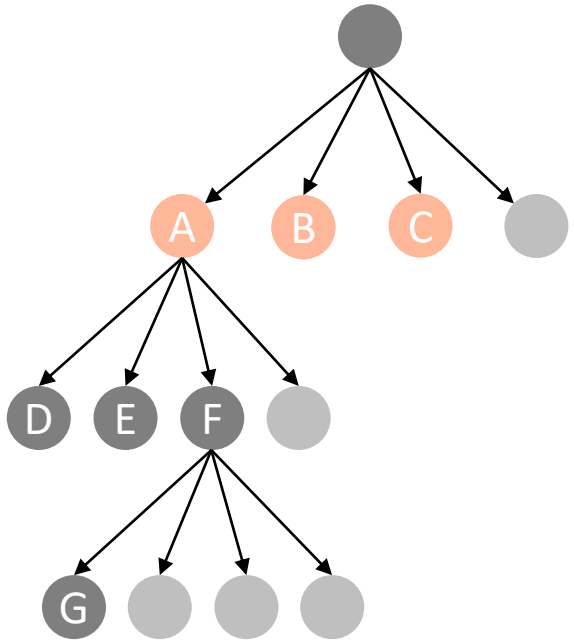
0

0

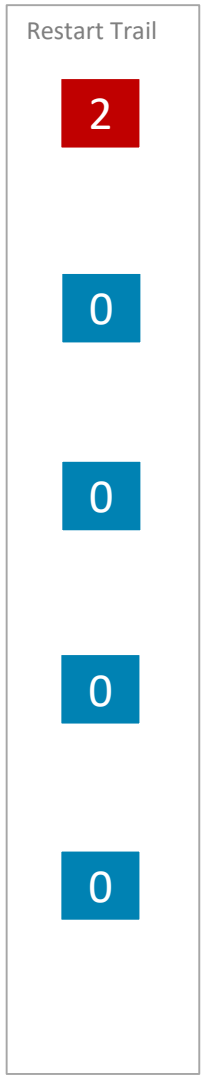
0

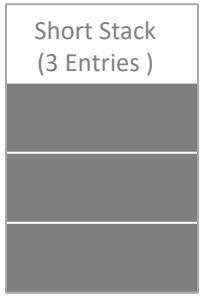
Short Stack
(3 Entries)

Example 4-Wide BVH Traversal

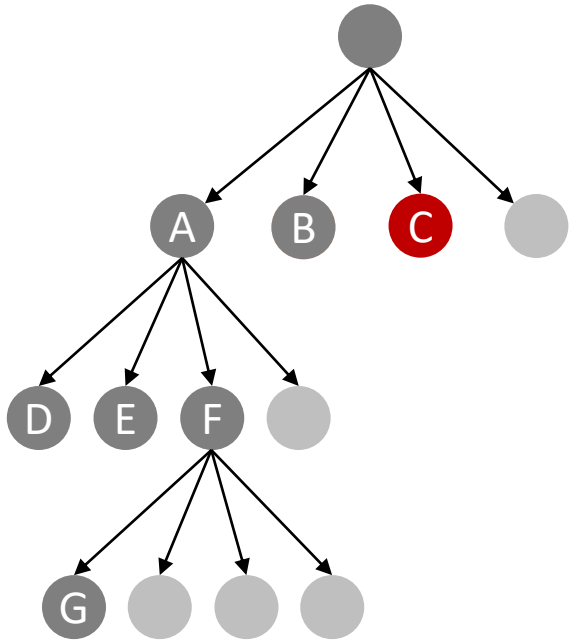


LEVEL = 0

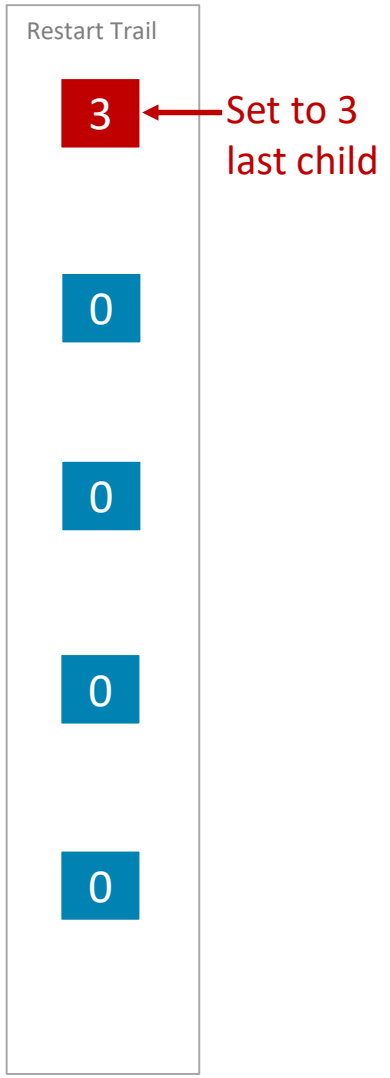


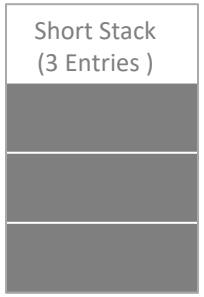


Example 4-Wide BVH Traversal

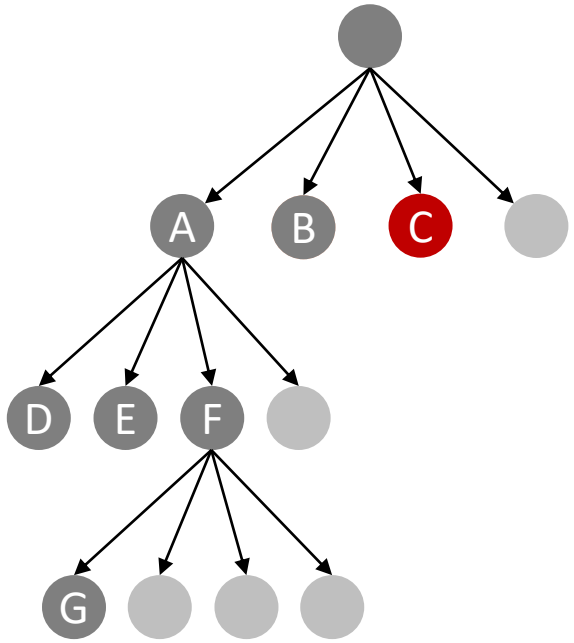


LEVEL = 1



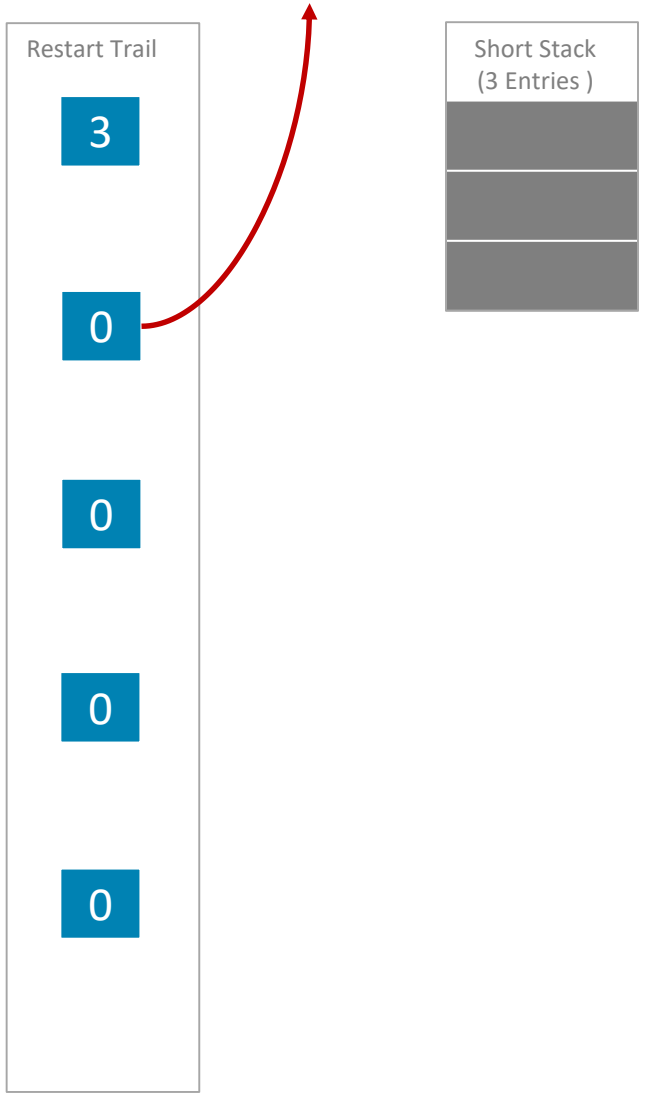


Example 4-Wide BVH Traversal

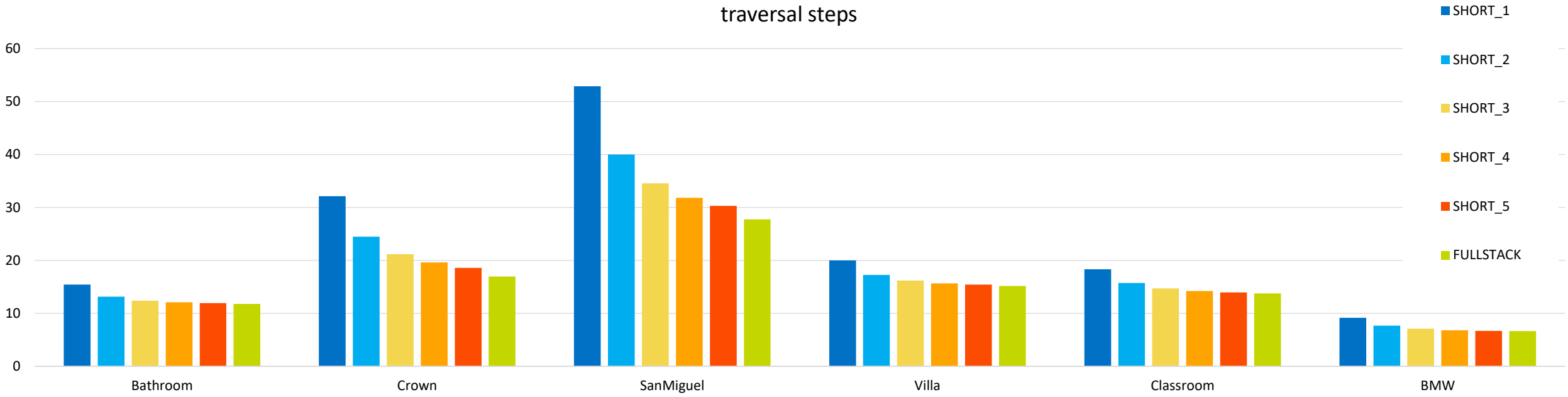


LEVEL = 1

Find closest level < 3



Results for 6-wide BVH



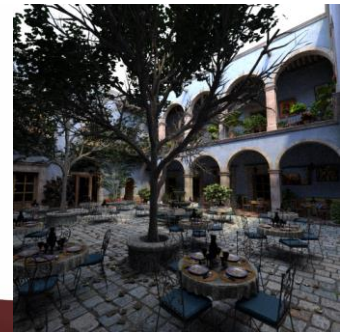

BATHROOM (592K)


BMW (792K)


VILLA (5.03M)


CLASSROOM (104K)


CROWN (3.54M)


SANMIGUEL(10.3M)

Stack culling

- Storing near distance on the short stack would allow culling of popped nodes when a closer hit was found

➔ memory overhead

- Alternatively one can process closest child and push the parent node onto the short stack for later re-intersection

➔ small culling overhead but often pays off

Conclusions

- Presented short stack with restart trail for wide BVHs
- Allows very compact stack storage at minimal overhead
- Suitable for fixed function ray tracing implementations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