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Ordered Depth-First Layouts for Ray Tracing

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Contents

- Background & Related Work
- Proposed method : Ordered depth-first layout (ODFL)
  - Comparison with depth-first layout
  - Tree construction and traversal for ODFL
- Experimental results
- Conclusions

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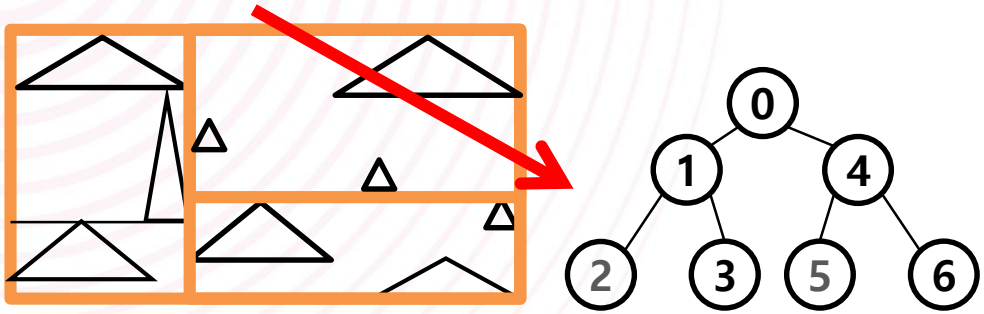
Background

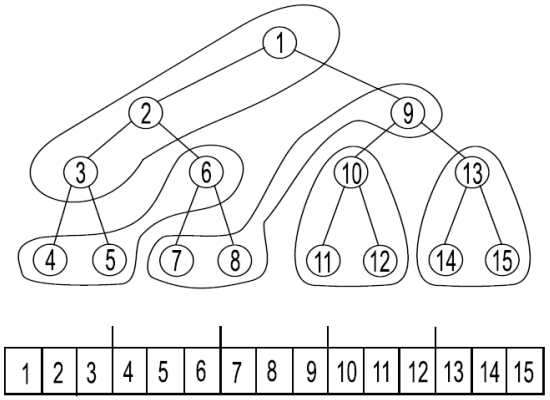


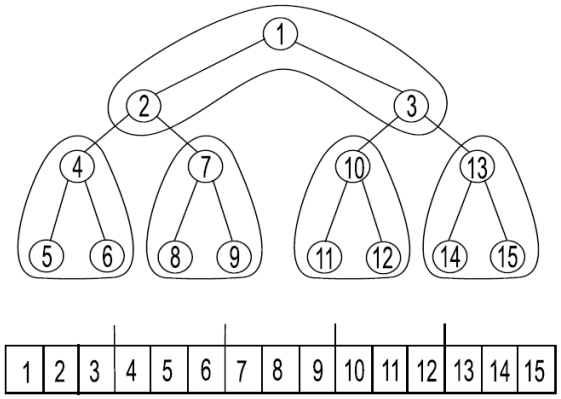
- Kd-tree
  - Axis-aligned BSP(binary space partitioning) tree
  - Widely used for computer graphics (e.g. ray tracing)

- Ray tracing with kd-trees
  - Requires many visits to nodes.
  - Important to design cache-efficient layouts

Related Work

These images are excerpted from [Hav 99].





- Depth-first layouts [PH10]
  - Basic tree representation from recursive tree building
  - Locality between the parent and the left child node
  - One pointer per node
- Subtree layouts [Hav99]
  - Made by clustering nodes
  - Locality between the parent and two child nodes
  - Two pointers per node (ordinary subtree)

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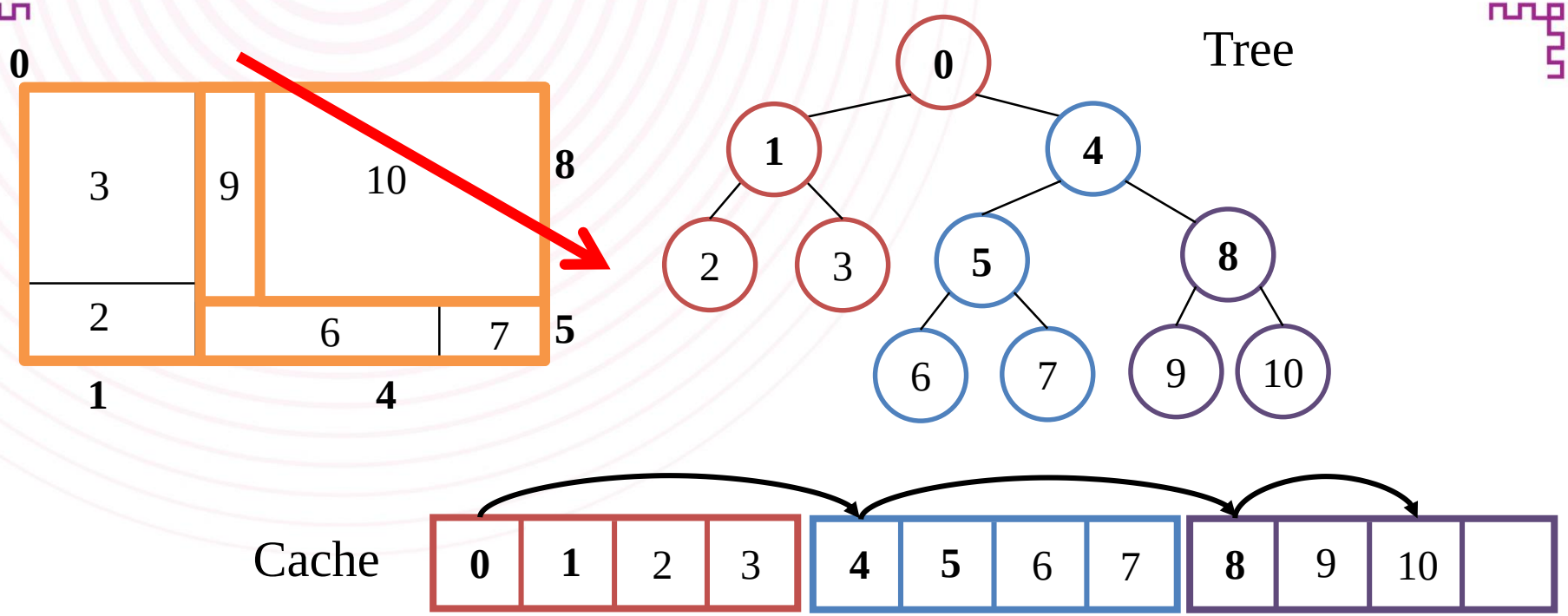
Proposed Method

- Goals
  - Improve the cache efficiency of depth-first layouts
  - No additional memory space (8 bytes per node)

- Our approach
  - The probability of a ray intersecting with a node is proportional to its surface area. [MB90]

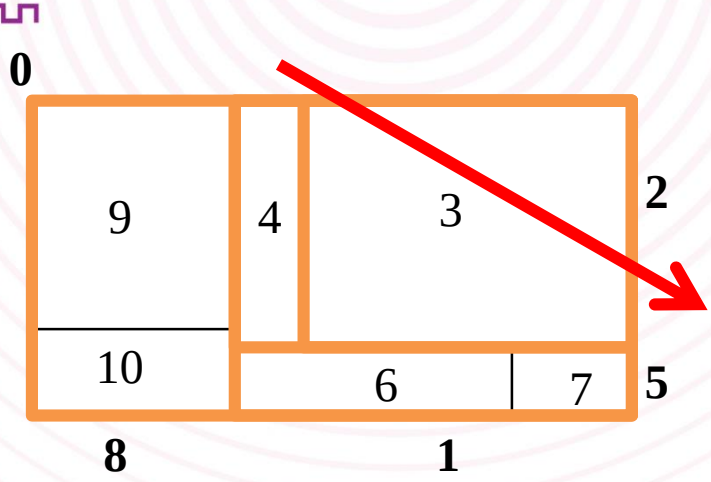
  - Change the arrangement criterion of child nodes
    : geometric position → surface area

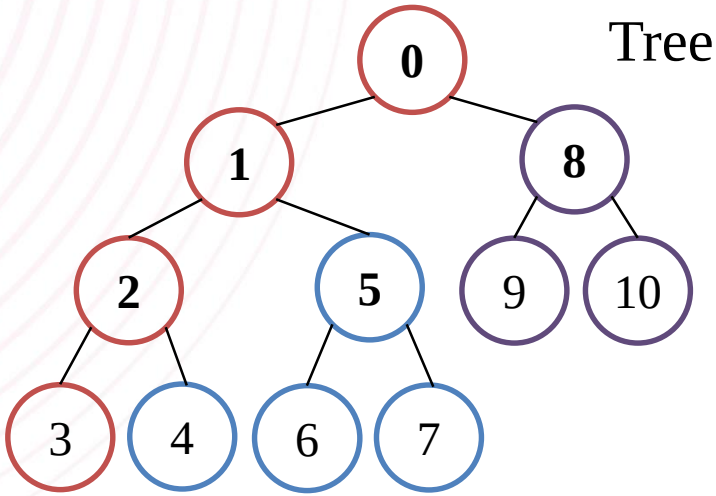
Traditional Depth-First Layout

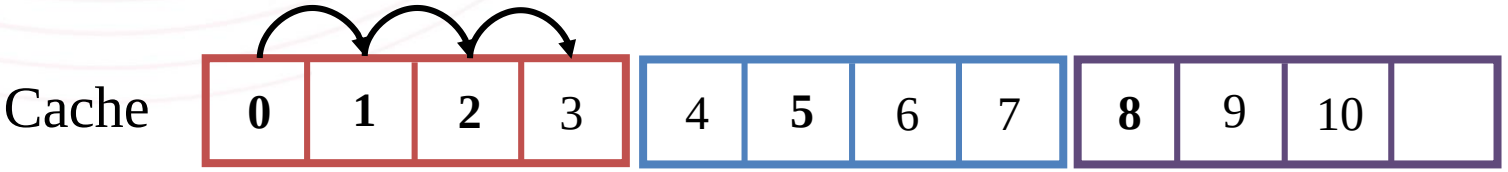


- Child nodes are arranged by their geometric position [PH10]
  (left node ≤ split plane ≤ right node)

Ordered Depth-First Layout (ODFL)







- Child nodes are arranged by their surface area (SA) (left node > right node)

Tree Construction and Traversal for ODFL

- Tree construction
  - SA values is obtained by a surface area heuristic (SAH)
  - Add a 1-bit reorder flag (embedded into a 8-byte node)
- Tree Traversal
  - For front-to-back traversal, the reorder flag is referenced

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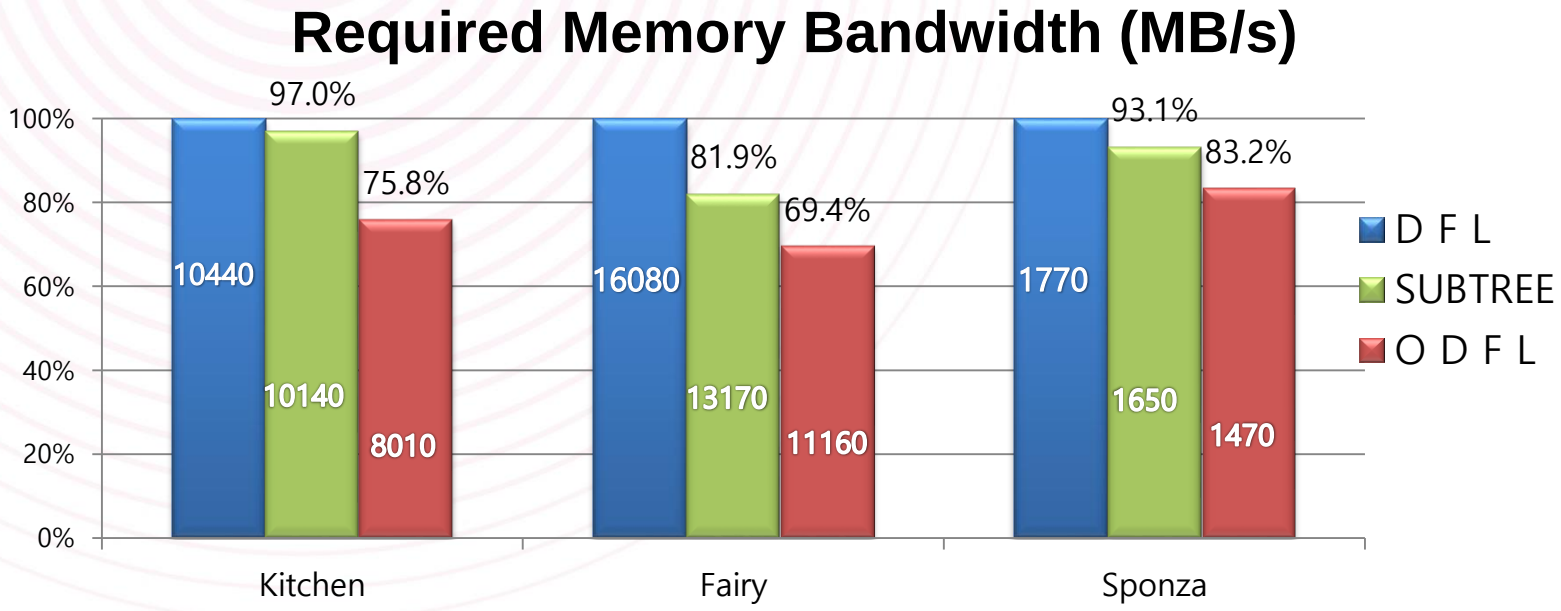
Experimental Setup

- Whitted ray tracer
  - Single-ray recursive tracing
  - Recursion depth 4
  - SAH-based tree build
- Dinero IV cache simulator[EH98]
  - 8KB size
  - 4-way set associative
  - 64byte block size
- Benchmark scenes (512x512 resolution)

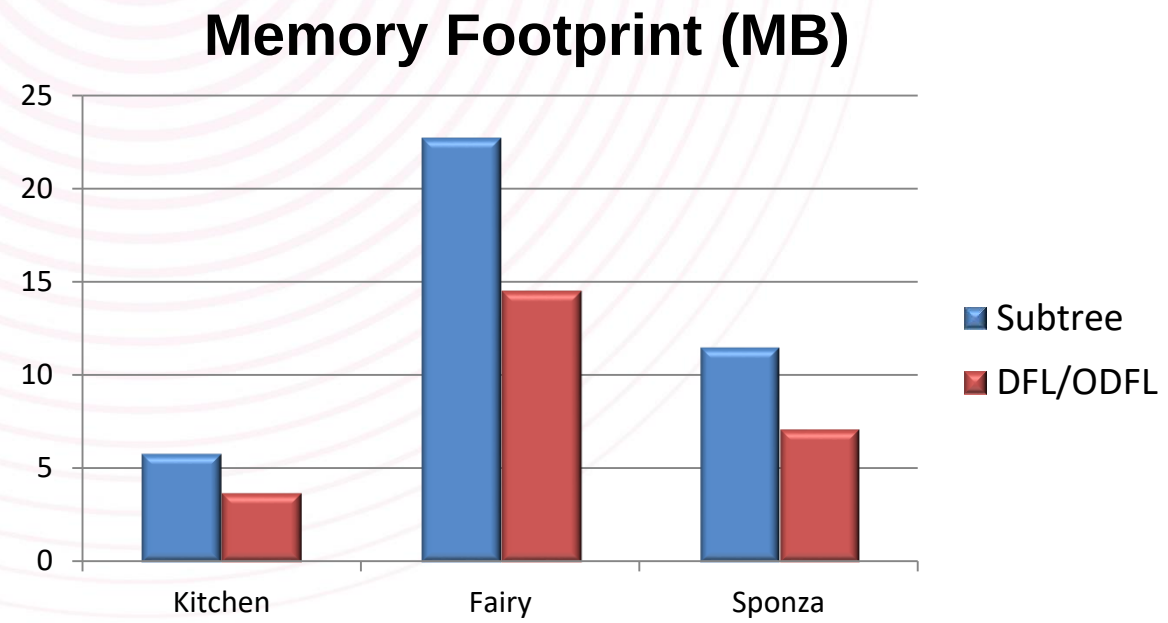
Kitchen Fairy Sponza

Results



- ODFL reduced the required memory bandwidth by
  - 15-30% compared with the depth-first layout
  - 10-21% compared with the ordinary subtree layout.

Results



- 40% less than the ordinary subtree layout
  - DFL/ODFL : 8 nodes per 64B cache block
  - Ordinary subtree : 5 nodes per 64B cache block

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Conclusions

- Maximize parent-child locality using simple node ordering
- Platform independent
  - Widely applicable to ray tracers based on CPUs, GPUs, and dedicated hardware
- Can be useful for other applications utilizing depth-first search
  - Collision detection, photon mapping, etc.

Acknowledgements

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Q&A