A Vectorized Traversal Algorithm for Ray-Tracing

José María Noguera Rozúa

University of Jaén

Carlos Ureña Almagro

Rubén J. García Hernández

University of Granada

Contents

- Introduction
- Previous Work
- Our Proposal
- Results
- Conclusions & Future work

Introduction I

- Ray-Tracing:
  - Very Realistic image synthesis.
  - Complex models supported.
  - Basis of many algorithms.
  - Traditionally slow.

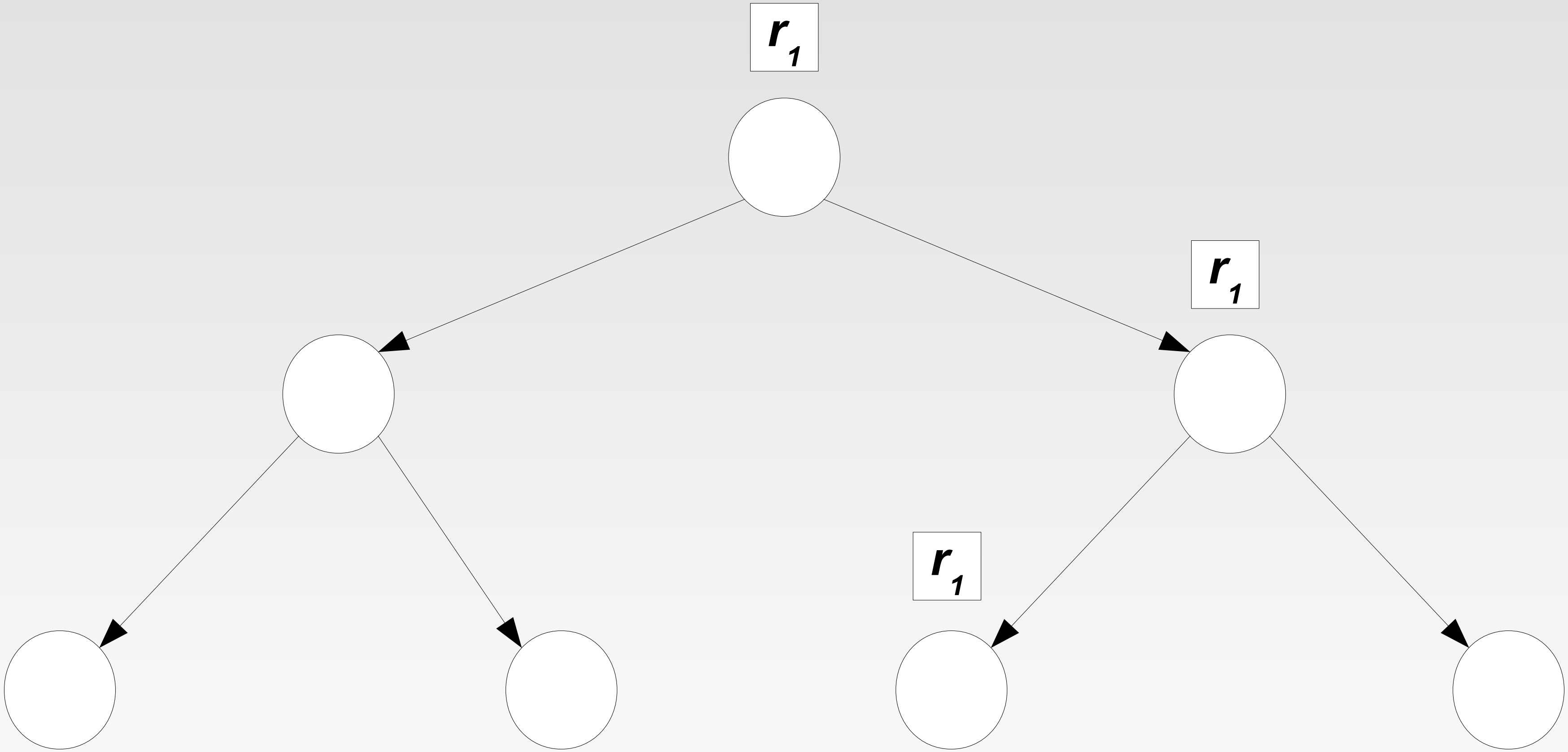
Introduction II

- Parallel Raytracers
  - Breadth-first traversal.
  - SIMD aware.
  - Some approaches use GPU.
  - High performance →

    Interactive / Real-Time RayTracing.

Previous work
Classic algorithm

- Traversal algorithm: Once per ray



Previous Work

Wald's algorithm I

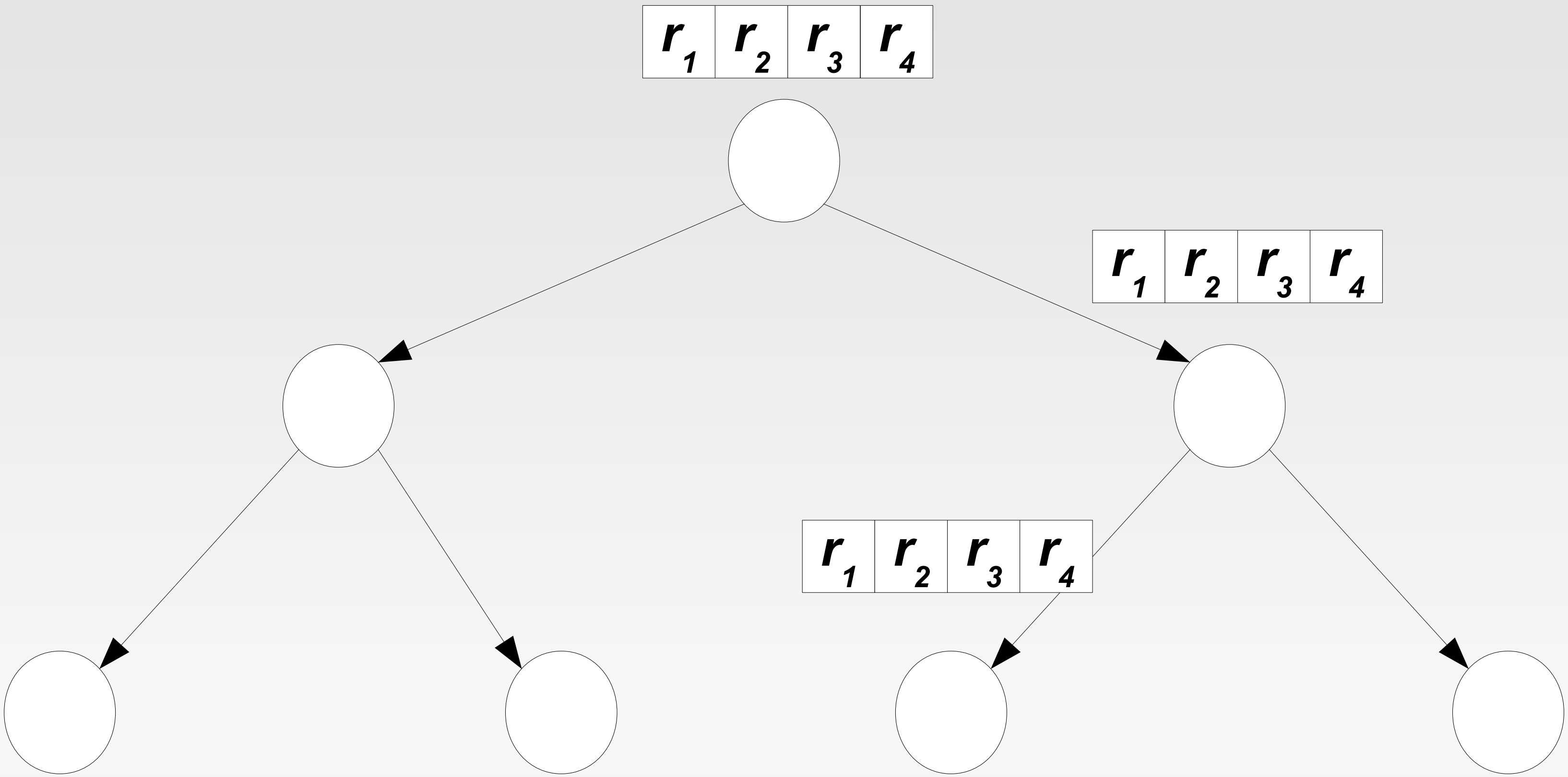
- Coherent rays:
  - Rays with the same origin and very similar direction will very probably hit the same objects.

- The algorithm uses a kd-tree and traverses it with 4-ray packets.

- Parallelism using Intel SIMD: SSE.

Wald's algorithm II

- Four ray traversal.



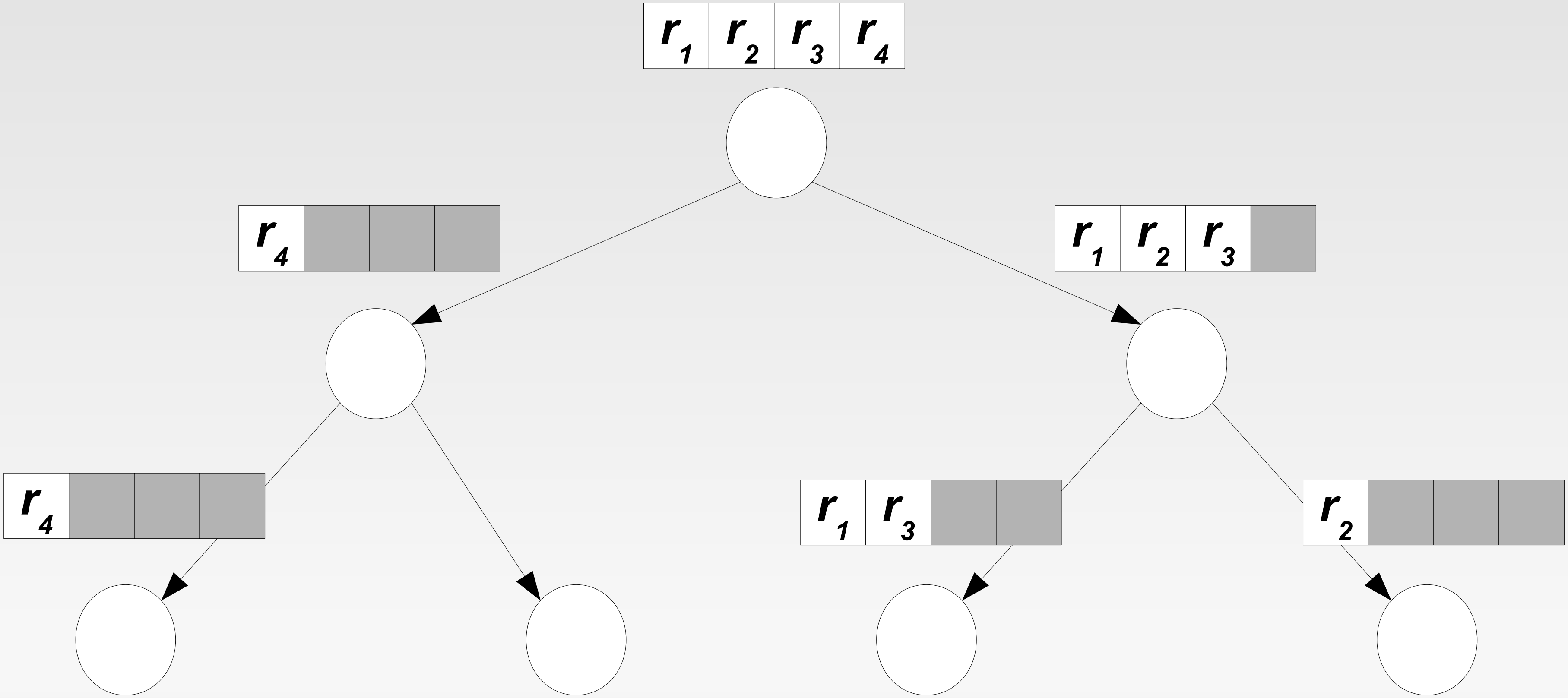
Motivation I

- Wald's algorithm limitations:
  - The gain in efficiency increases with ray coherency.
  - It's easy to select coherent primary rays in Ray-Tracing or Path-Tracing.
  - For secundary rays in Ray-Tracing, or other applications, rays are not coherent.
    - Gain is therefore smaller.

Our Proposal

Motivation II

- With non-coherent rays, packets tend to break, decreasing parallelism.



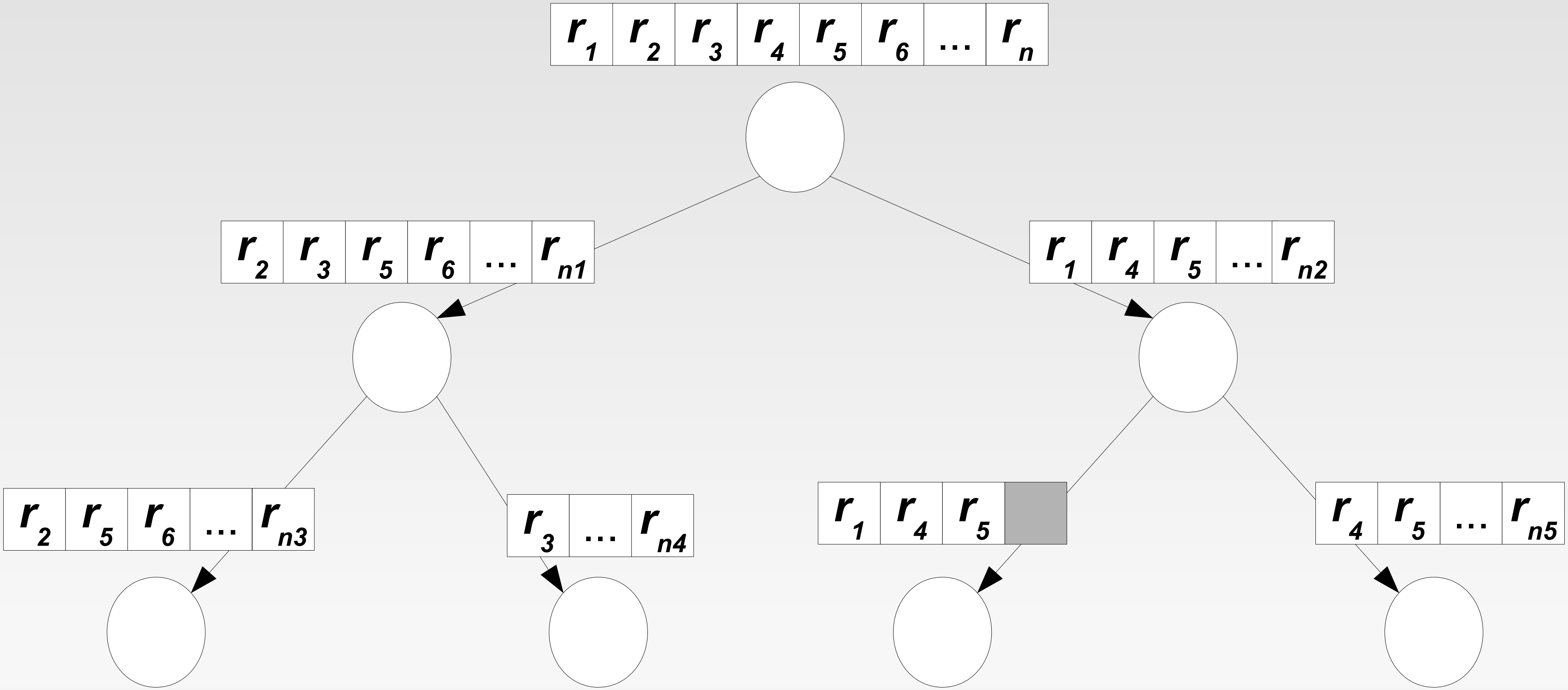
Our Proposal

Description

- We propose traversing the kd-tree only once but with all rays at the same time.
- Rays are classified during the traversal process:
  - No additional effort needed.
  - Coherence is increased in terminal nodes.
- We aim for maximum parallelization.

Our Proposal
Traversal Algorithm I

- Traversal for n rays.



Our Proposal

Traversal Algorithm II

- Problem:
  - Appears when looking for the first intersection (typical in raytracing and other applications).
  - We want the ability to stop the traversal of a ray when finding its first intersection.
  - Different rays may mean different traversal order of the tree.

Our Proposal

Traversal Algorithm III

- Solution:
  - Classify the rays in eight groups according to their director vectors.
  - Run the algorithm for each group.

Our Proposal
Advantages

- Advantages:
  - If 2 or more rays cross the same node, they will do it together.
  - Increases the possibilities of having rays available to process in parallel.
  - Non-coherent rays will be classified when going down the tree.
  - The number of traversals of the tree, and the number of triangle accesses is reduced.

Our Proposal

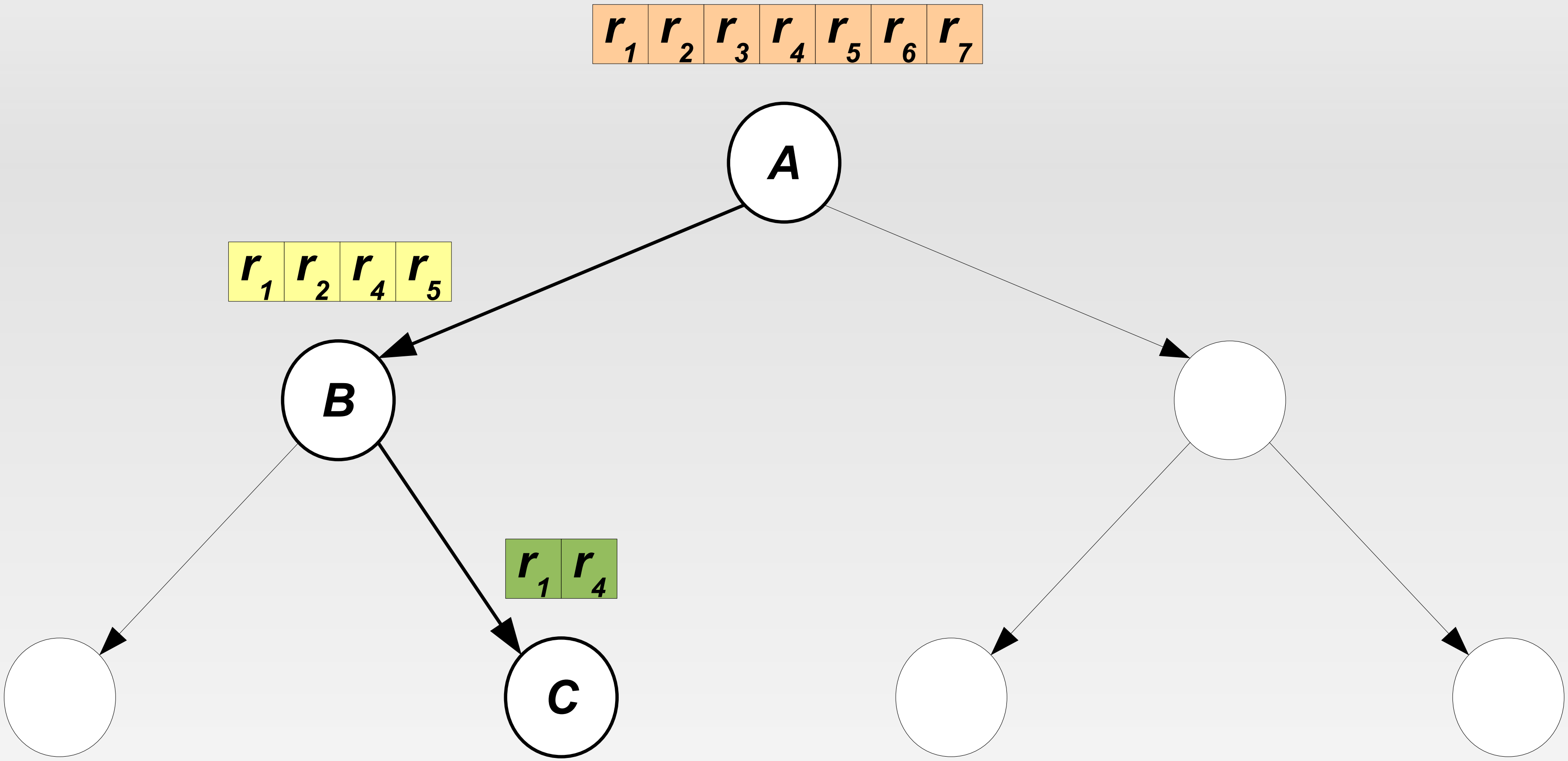
Memory layout of rays I

- A global data structure for the rays:
  - Stores all rays and their attributes (director vector, origin, intersected triangle id...)

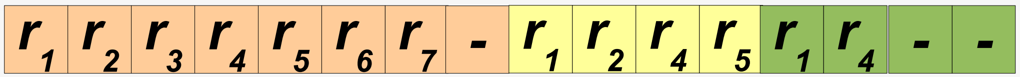
- A ray stack:
  - Stores only the values for the ray traversal depending on the current node.
  - Pointer to the rest of the information in the structure above.
  - SSE optimized ”Structure of Vectors”.

Our Proposal

Memory layout of rays II



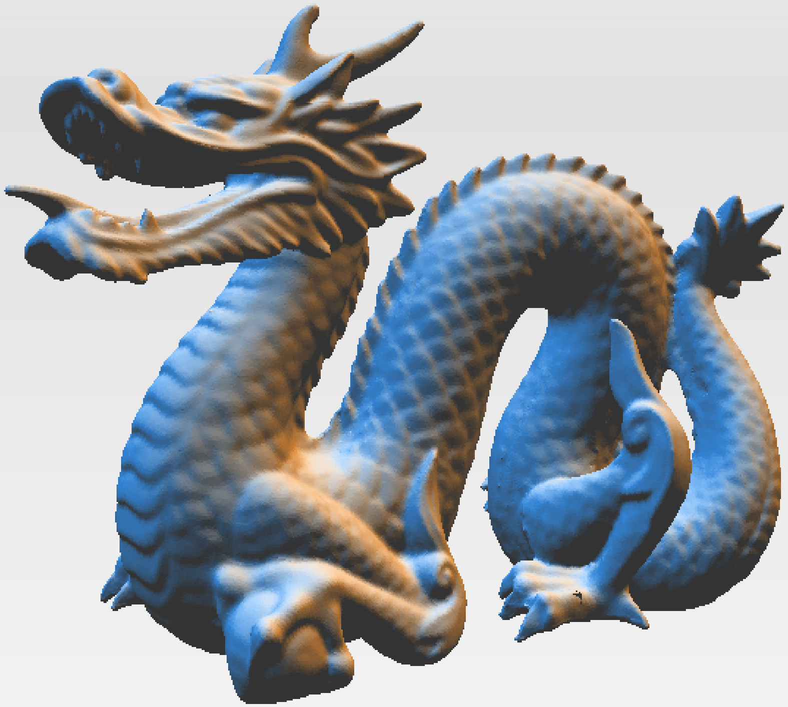
State of the Ray Stack in node C:



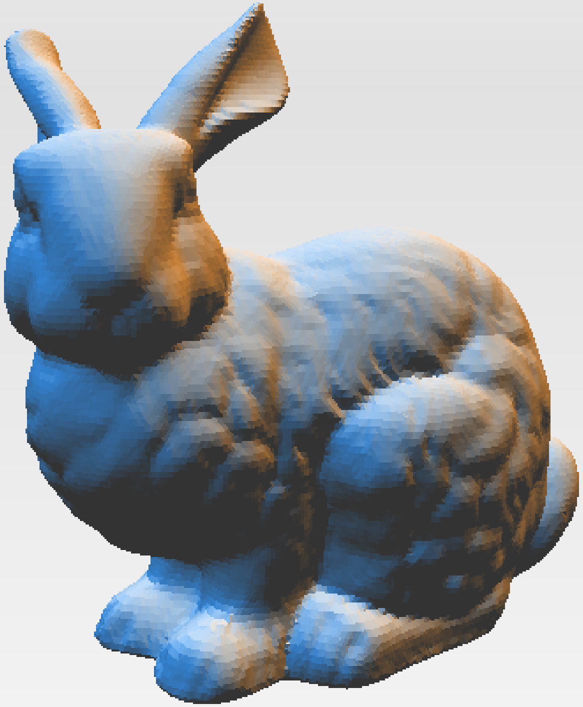
Performance I

- Tests with coherent rays (Ray-Tracing's primary rays – 1 ray per pixel)
  - Classic algorithm, 1 traversal per ray.
  - Wald's algorithm, 1 traversal per 4-ray packet.
  - Wald's algorithm, 1 traversal per 64-ray packet.
  - Proposed algorith, 1 traversal for each group of rays with direction vector in the same octant.
- Test with non coherent rays
  - Random rays with uniform distribution.

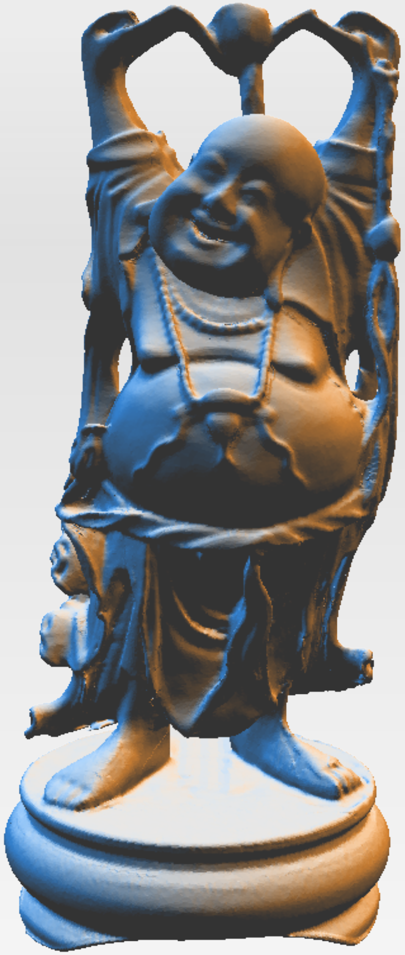
Performance II



Dragon
0,8 M tri.

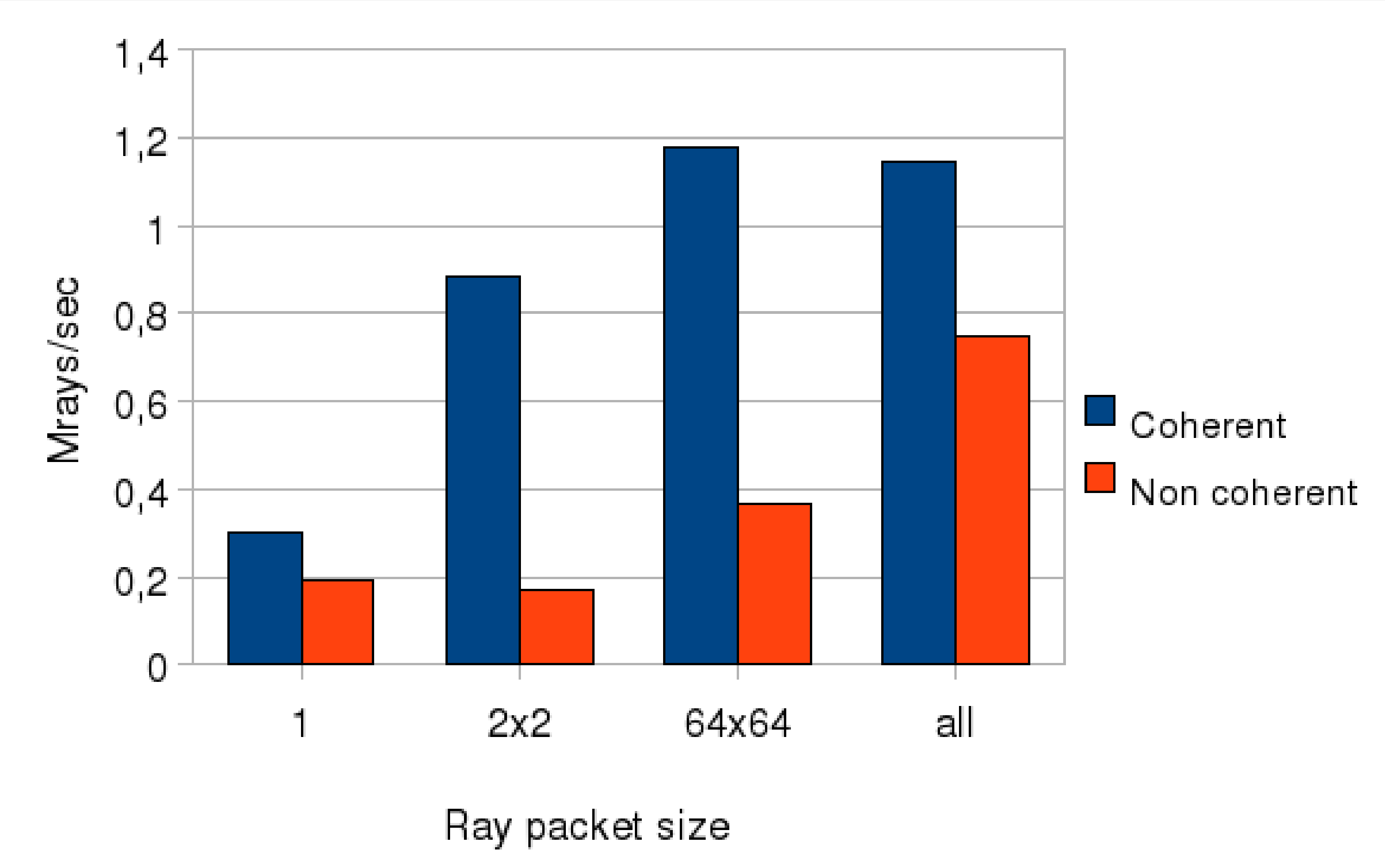


Stanford Bunny
0,069 M tri.



Happy Buddha
1,1 M tri.

Performance III



Buddha, 1.1MTri, 1280x1024

Conclusions & Future Work

- Our technique allows:
  - More parallelization to be extracted even for non-coherent rays.
  - Visiting each node at most eight times. Less access to nodes and their triangles.
- Future work: larger SIMD width → GPU