Real-Time Realism will require...

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Ray Tracing vs Rasterization?

- Many similarities in how visibility is computed
  - Not really a big conceptual difference

- Explore that a bit here...

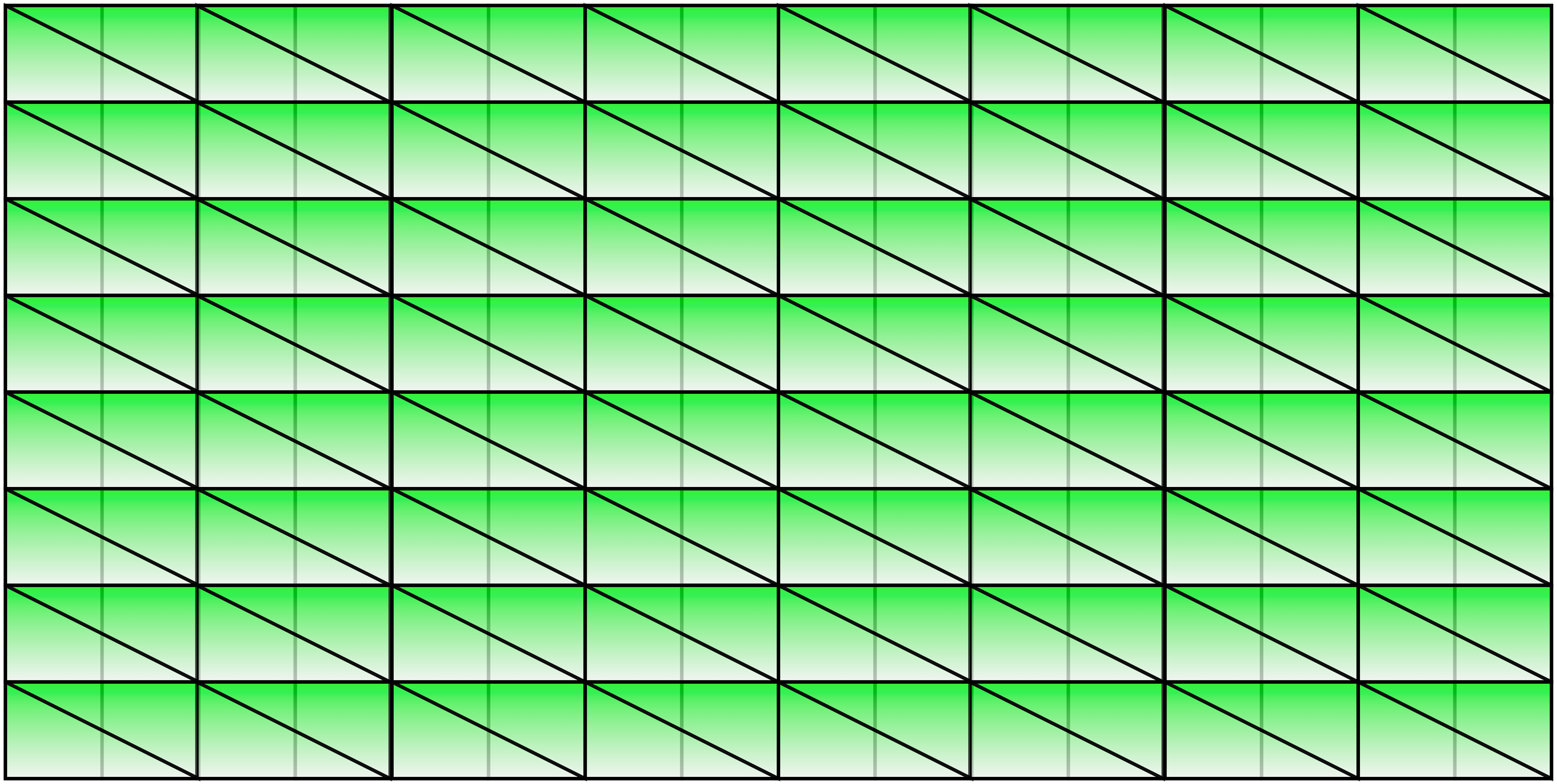
Ray/sample in triangle testing

- Ray/triangle intersection
  - Most tests are basically *signed volume* computations [Kensler & Shirley, IRT 2006]
  - Hanrahan did similar things in *homogeneous* coords
- Sample/triangle rasterization
  - Could use edge equations [Pineda88] or *homogeneous* edge equations [Olano & Greer 97]
  - Equivalent to testing if the sample is on the "right" side of the plane from the viewer through a triangle edge
  - That is, a *signed volume*

Complexity analysis

- The usual arguments for ray tracing:
  - Ray tracing is $O(\log n)$, while...
  - ...rasterization is $O(n)$
- Why is rasterization so successful for coherent rays?
  - The GPU? Not only...
- For *coherent* rays, the analysis above is not quite correct (I think).

Coherent rasterization complexity



- Approximately 1-2 triangles per pixel
- $O(\log n)$ for ray tracing
- $O(1)$ for rasterization

Rasterization complexity

- For coherent rays, $O(d)$ per pixel, where d is the depth complexity
- Wonderful paper by Cox & Hanrahan 1993, showed that overdraw is:

$$1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \cdots + \frac{1}{d} \approx \ln(d) + \gamma$$

$$\gamma = 0.57721\ldots$$

- So, $O(\log d)$ for shading
- However, with shading after visibility (deferred): $\approx O(1)$ shading cost
  - Similar to ray tracing

More complexity

- In rasterizers, we use coarser BVH to cull outside frustum
    - Ray tracing is ≈ view frustum culling for 1 pixel
    - So rasterization complexity is (for arbitrary rays): $O(\log n + kd)$
        - Leaf node sizes are different, hence the k, where $k > 1$
    - Now, if you only want coarse visibility, rasterization becomes interesting again
    - Plus, rasterization basically builds a projected uniform grid in camera space [Hunt & Mark 08]
- Ray tracing can use small frusta around packets of rays as well
    - Ray tracing starts to resemble rasterization for coherent rays

Visibility differences

	Ray tracing	*Rasterization*
Point/ray inside triangle	Signed volumes, i.e., ≈plane through edge dot ray	Homogeneous edge equations = "planes" through tri edges
Acceleration data structure	Yes, BVH/Kd-tree down to the *individual* triangles	Yes, BVH down to *groups* of triangles + builds (on-the-fly) uniform grid in projected space
Primary rays	$O(\log n)$ or a bit faster	At most $O(d)$
Secondary rays	$O(\log n)$	$O(\log n+kd)$
(Shading)	$O(1)$	Could be $O(1)$ with "deferred," otherwise $O(d)$

Possible conclusion

Ray tracing and rasterization are "converging" to the same visibility algorithm

(in a broad sense)

- Examples:
  - Micropolygon Ray Tracing with Defocus and Motion Blur by Hou et al., SIGGRAPH 2010
    - Ray tracing using BVH, then basically rasterization when you reach the leaves
  - Low-res hierarchical "rasterization" of indirect light
    - [Bunnell 2005], [Christensen 2008],[Ritschel et al., 2009]
- Likely, we will see new combinations soon

Back to the 1970-80’s

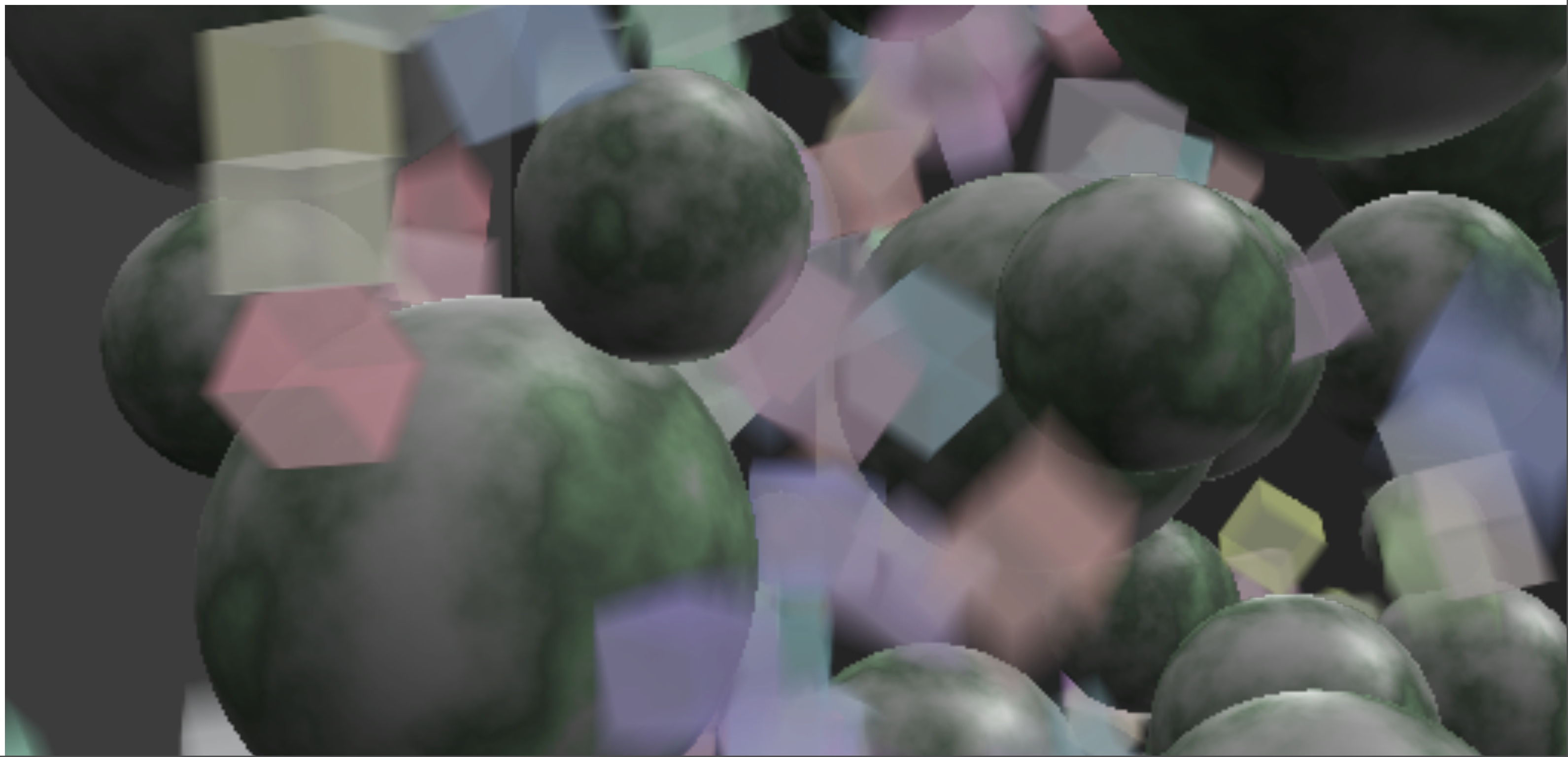
- I *think* that (near-term and good-enough) real-time realism will require a lot of:

Innovation in visibility algorithms

- ...but this is only *one* ingredient.

Lots of progress in visibility lately

- Stochastic rasterization is hot... again
  - [Akenine-Möller et al., GH 2007], [Toth & Linder, MSc thesis 2008], [Hou et al., SIGASIA 2009], [McGuire et al., HPG 2010]
- Decoupled shader caching
  - [Hasselgren & Akenine-Möller, EGSR 2006],[Ragan-Kelley et al. TOG 2010], [Burns & Fatahalian, HPG 2010]
- Analytical
  - Bandwidth/compute gap continues to grow, so might make more sense now and in the future
  - [Gribel et al. HPG2010]
- Combinations:
  - [Bunnell 2005], [Christensen 2008], [Ritschel et al., 2009]
  - [Hou et al. 2010]



Visibility API?

- Really Matt Pharr's idea! Double check with Matt!
- Make it easier to explore new ideas?
- Visibility in near future is probably a mix between ray tracing, rasterization, analytical and point sampling.

Thanks for listening!

...and thanks to the Advanced Rendering Technology group at Intel for feedback!