Anti-aliasing and Acceleration

CSE 457, Autumn 2003

Graphics

http://www.cs.washington.edu/education/courses/457/03au/

Readings and References

Readings

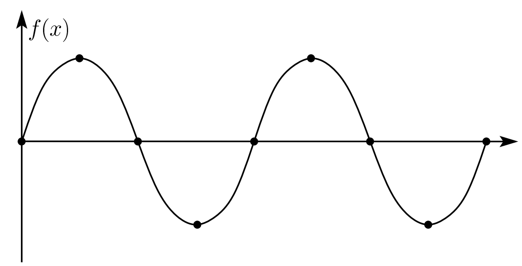
- Sections 12.5.3 – 12.5.4, 14.7*, 3D Computer Graphics*, Watt

Other References

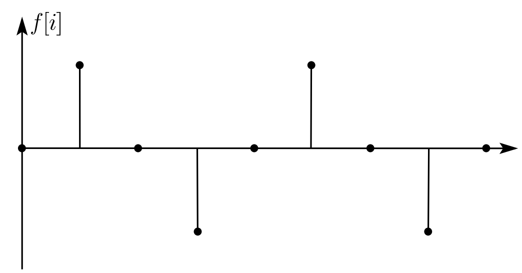
- A. Glassner. An Introduction to Ray Tracing

Aliasing

- Ray tracing is a form of sampling and can suffer from annoying visual artifacts...
- Consider a continuous function $f(\mathrm{x})$. Now sample it at intervals Δ to give $f[i] = \text{quantize}[f(i\Delta)]$.
  - » The question is, how well does $f[i]$ approximate $f(\mathrm{x})$?
- Consider sampling a sinusoid:



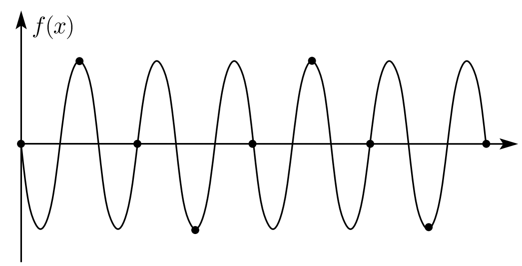
- In this case, the sinusoid is reasonably well approximated by the samples.



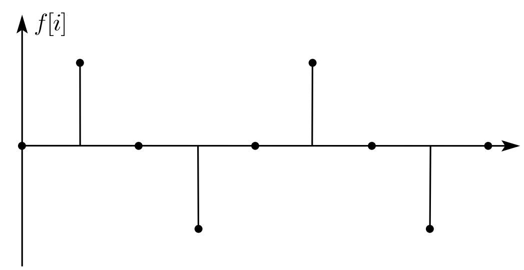
Aliasing (con't)

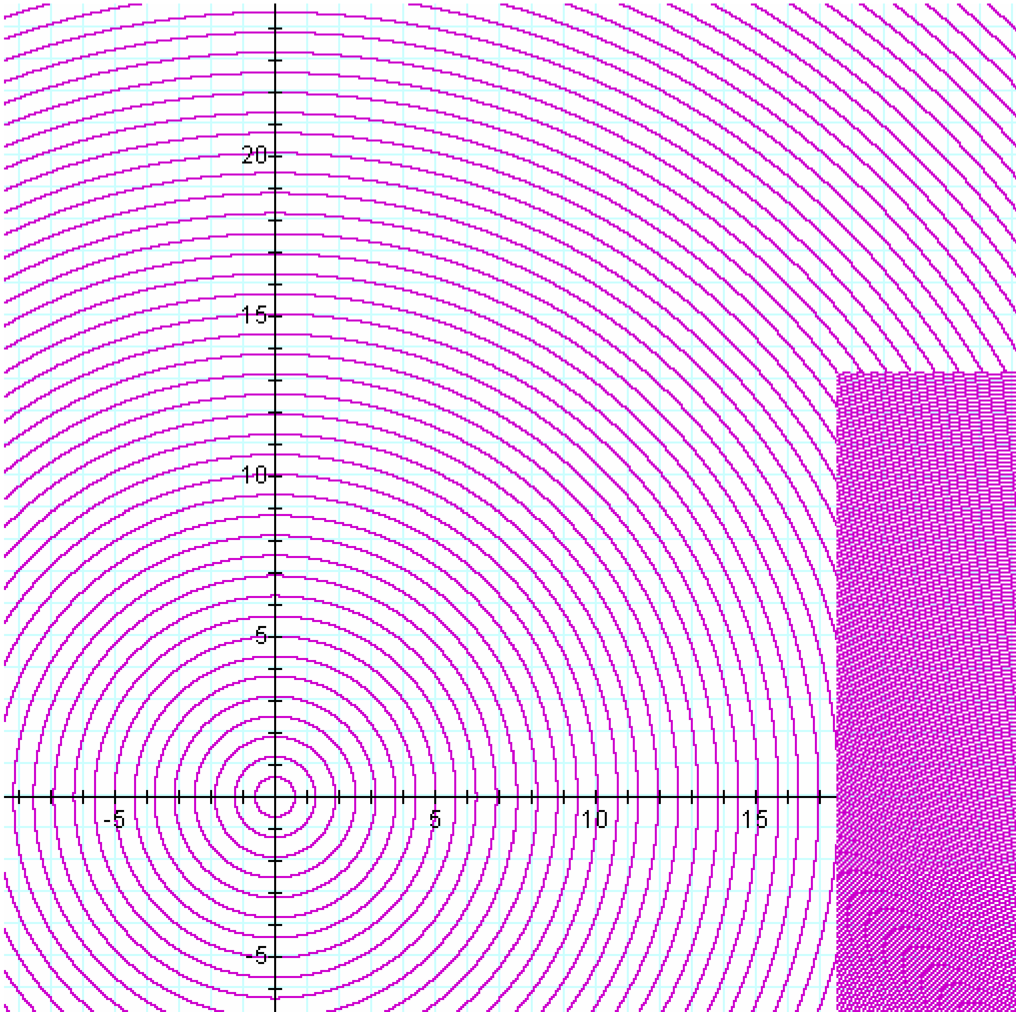
- Now consider sampling a higher frequency sinusoid

- We get the exact same samples, so we seem to be approximating the first lower frequency sinusoid again.



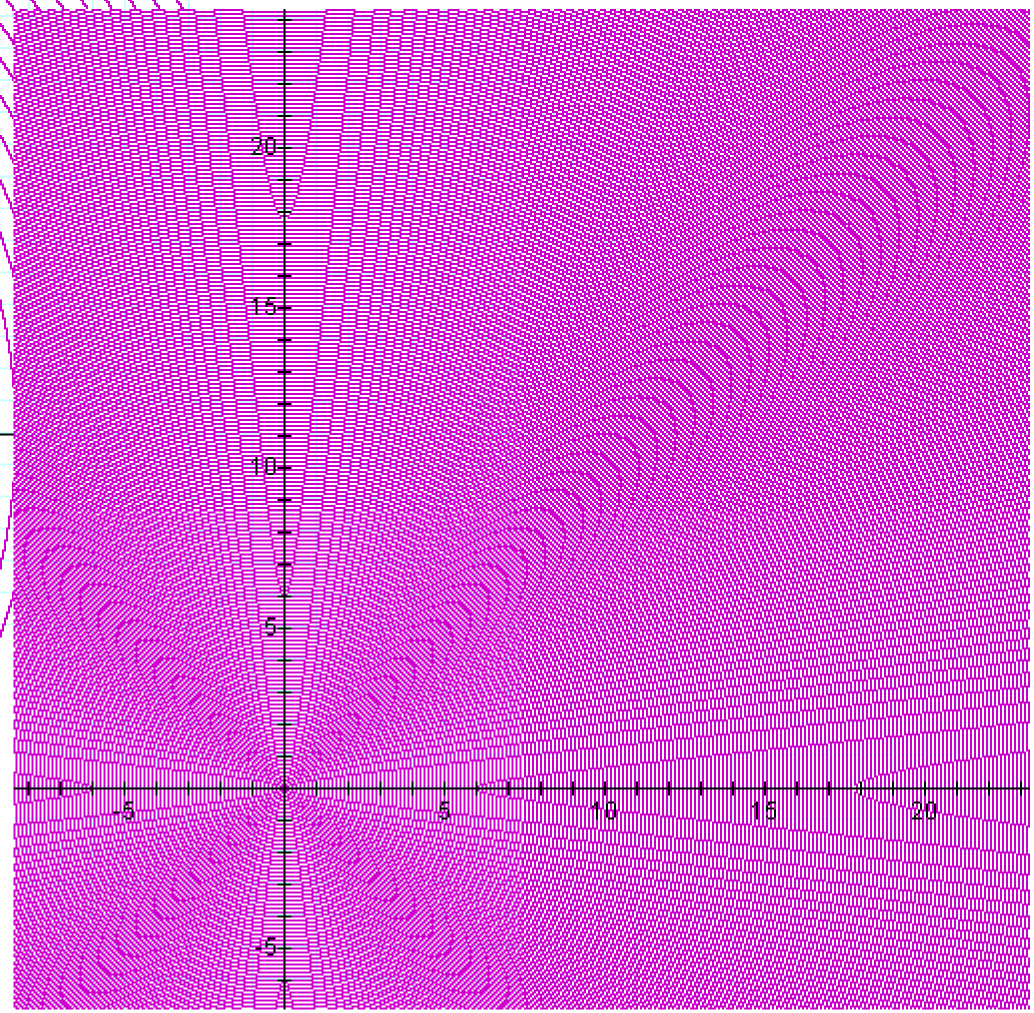
- We say that, after sampling, the higher frequency sinusoid has taken on a new "alias", i.e., changed its identity to be a lower frequency sinusoid.





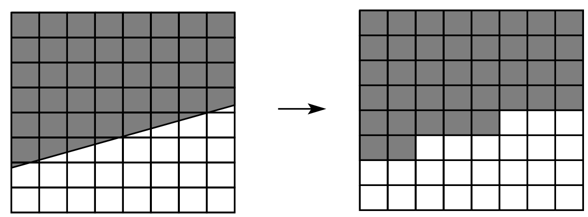
sin(5r)=0

sin(25r)=0

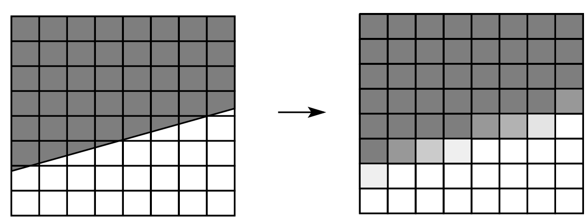


Jaggies

- One of the most common rendering artifacts is the "jaggies". Consider rendering a white polygon against a black background:



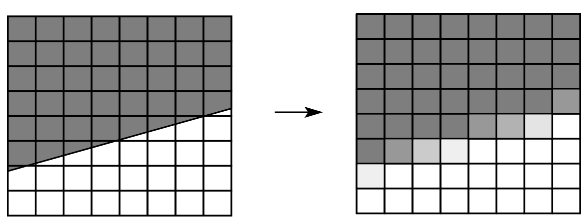
- We would instead like to get a smoother transition:

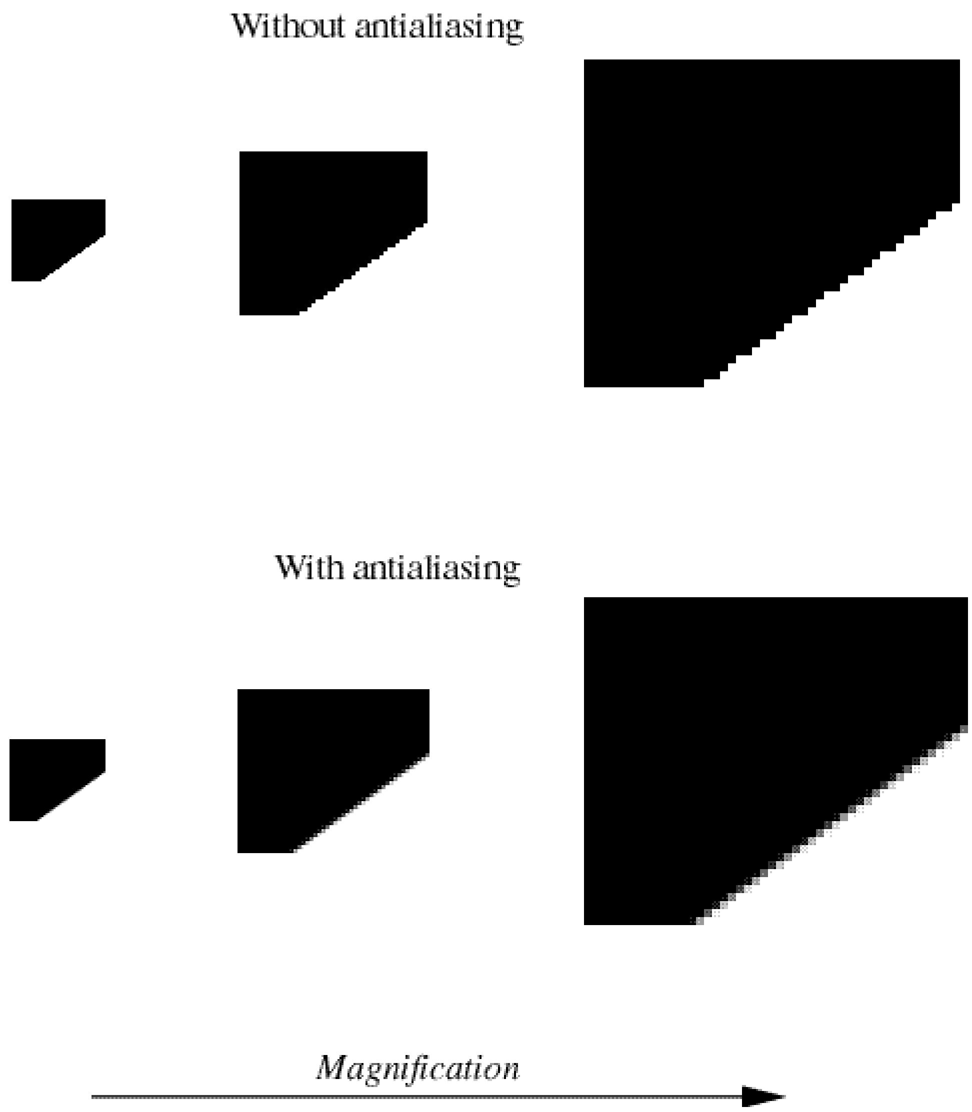


Anti-aliasing

- **Q**: How do we avoid artifacts caused by sampling?
- Sampling:
- Pre-filtering:
- Combination:

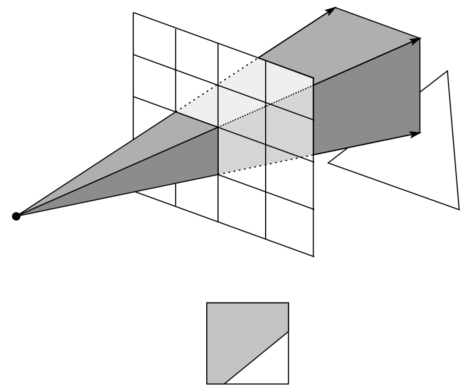
- Example - polygon:



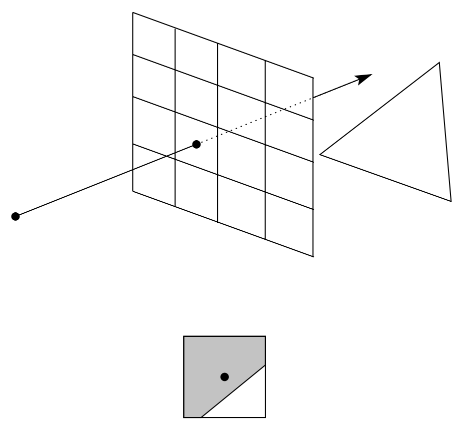

Without antialiasing
With antialiasing
Magnification

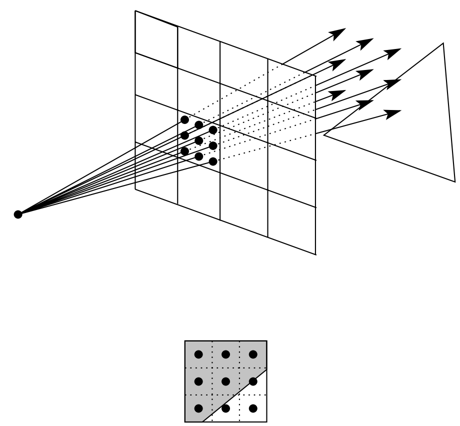
Antialiasing in a ray tracer

- We would like to compute the average intensity in the neighborhood of each pixel.



- When casting one ray per pixel, we are likely to have aliasing artifacts.
- To improve matters, we can cast more than one ray per pixel and average the result.
- A.k.a., **super-sampling and averaging down**.



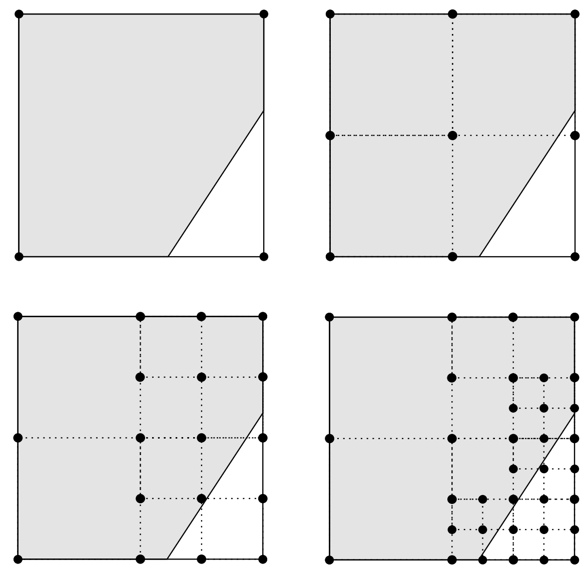


Speeding it up

- Vanilla ray tracing is really slow!
- Consider: m x m pixels, k x k supersampling, and n primitives, average ray path length of d, with 1 or 2 rays cast recursively per intersection.
- Complexity =
- For m=1,000, k = 5, n = 100,000, d=8…very expensive!!
- In practice, some acceleration technique is almost always used.
- We've already looked at reducing d with adaptive ray termination. Now we look at reducing the effect of the k and n terms.

Antialiasing by adaptive sampling

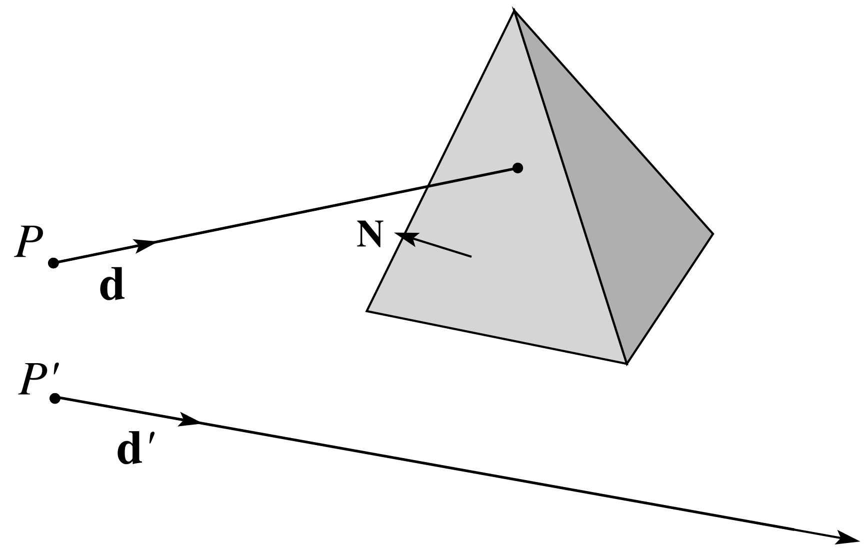
- Casting many rays per pixel can be unnecessarily costly.
- For example, if there are no rapid changes in intensity at the pixel, maybe only a few samples are needed.
- Solution: **adaptive sampling**.



- **Q**: When do we decide to cast more rays in a particular area?

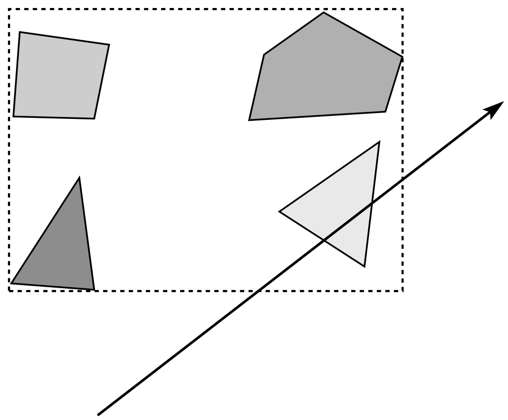
Faster ray-polyhedron intersection

- Let's say you were intersecting a ray with a polyhedron:

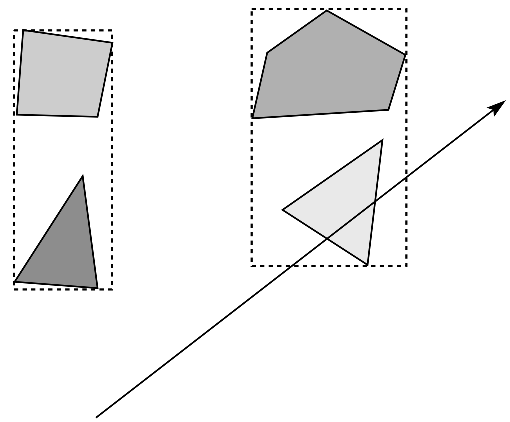


- Straightforward method
  - » intersect the ray with each triangle
  - » return the intersection with the smallest *t*-value.
- **Q**: How might you speed this up?

Hierarchical bounding volumes

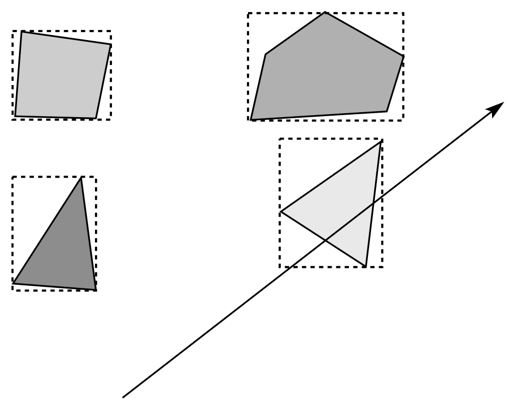


Intersect with largest B.V...



...then intersect with children...

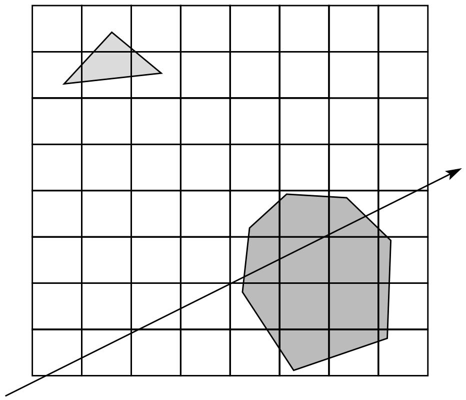
Balanced trees with tight bounding volumes.



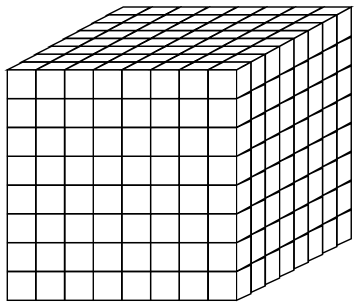
...until you reach the leaf nodes - the primitives.

Uniform spatial subdivision

- Another approach is **uniform spatial subdivision**.



Uniform subdivion in 2D

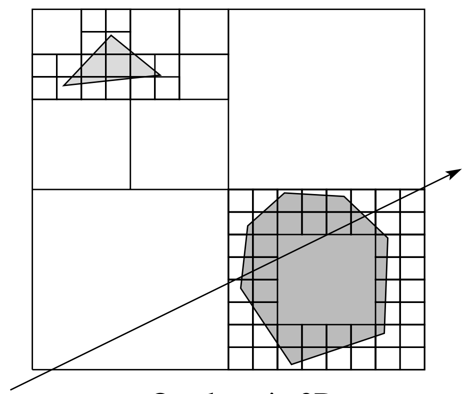


Uniform subdivion in 3D

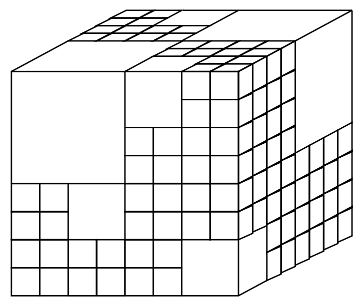
- Idea:
  - » Partition space into cells (voxels)
  - » Associate each primitive with the cells it overlaps
  - » Trace ray through voxel array *using fast incremental arithmetic* to step from cell to cell

Non-uniform spatial subdivision

- Still another approach is **non-uniform spatial subdivision**.



Quadtree in 2D



Octree in 3D

- Other variants include k-d trees and BSP trees.

- Various combinations of these ray intersections techniques are also possible. See Glassner for more.

Summary

- What to take home from this lecture:
  - » The meanings of all the boldfaced terms.
  - » An intuition for what aliasing is.
  - » How to reduce aliasing artifacts in a ray tracer
  - » An intuition for how ray tracers can be accelerated.