

Ray Tracing Details

Reading

Required

- Foley & van Dam, Section 16.12.1-5

Optional

- Hearn & Baker, Section 14.6
- This lecture is on some extensions that you can consider for your Trace project.

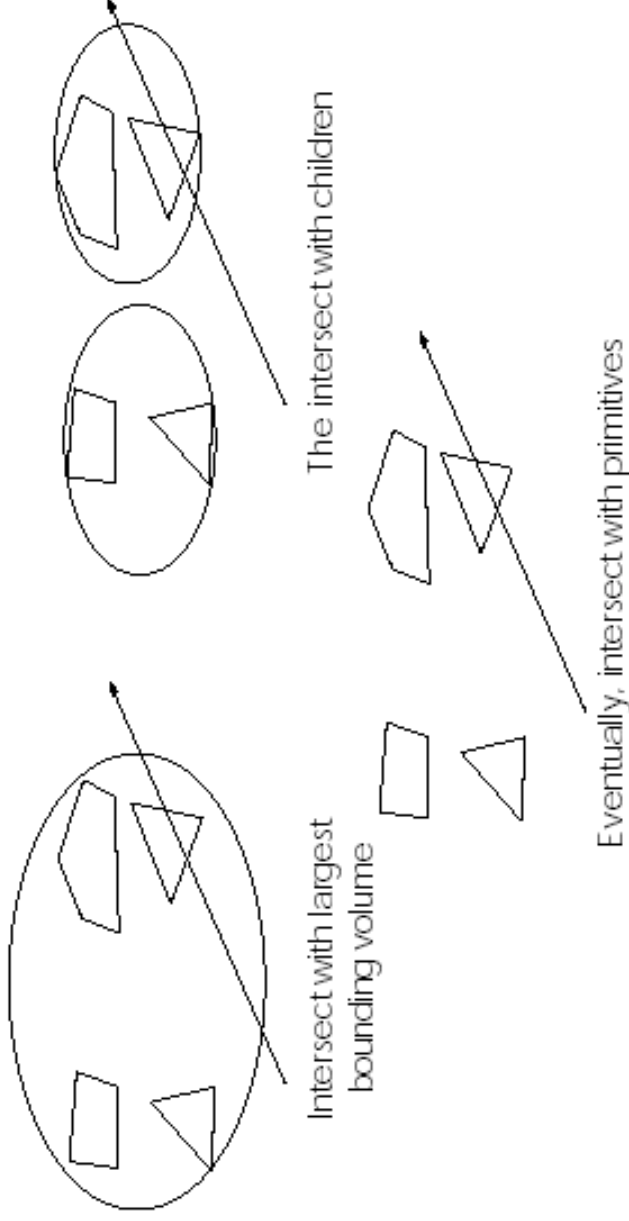
Goodies

- There are some advanced ray tracing features that self-respecting ray tracers shouldn't be caught without:
 - Acceleration techniques
 - Antialiasing
 - CSG
 - Distributed ray tracing
- There are some features that dramatically increase the power of a ray tracer:
 - Particle systems
 - Caustics and participating media
 - ...

Acceleration Techniques

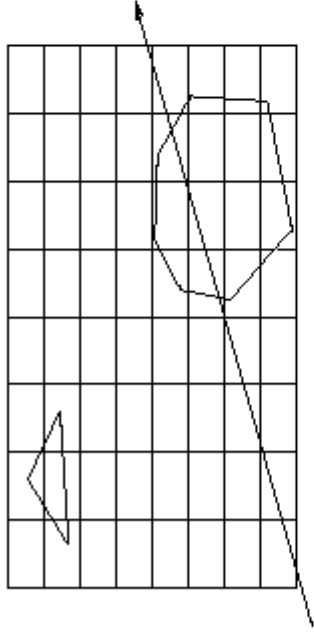
- Problem: ray-object intersection is very expensive
- So make intersection tests faster and do fewer tests

Hierarchical Bounding Volumes

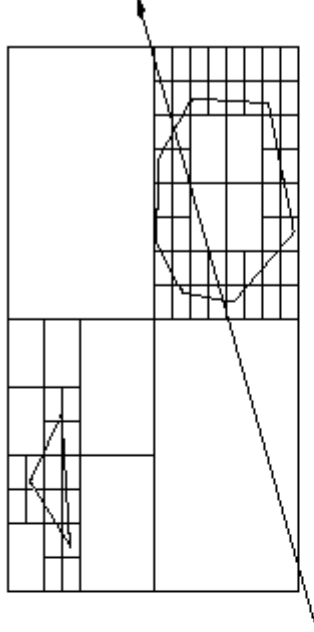


- Arrange scene into a tree, like your hierarchical model
 - Interior nodes contain primitives with very simple intersection tests (e.g., spheres). Each node's volume contains all objects in subtree (e.g., bounding spheres).
 - Leaf nodes contain original geometry
- Like BSP trees, the potential benefits are big but the hierarchy is hard to build

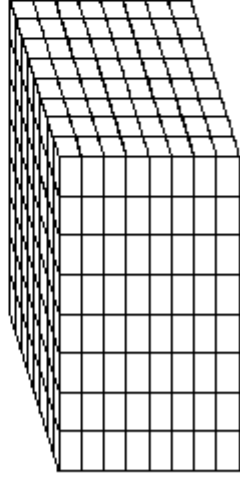
Spatial Subdivision



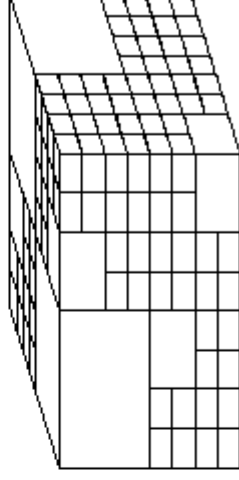
Uniform subdivision
in 2D



Quadtree



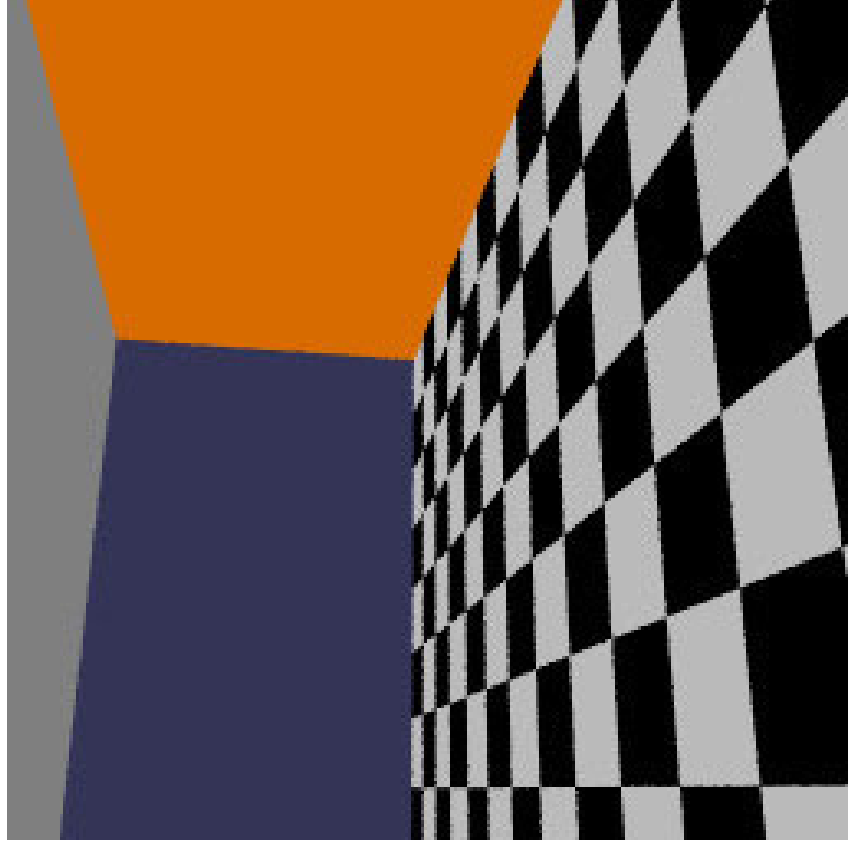
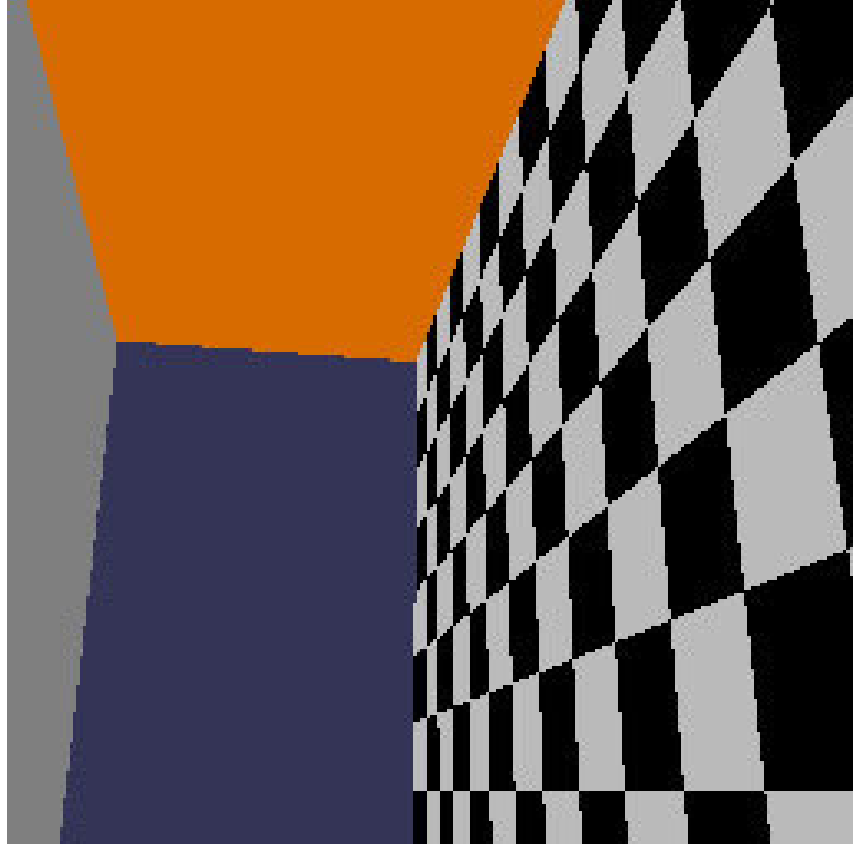
Uniform subdivision
in 3D



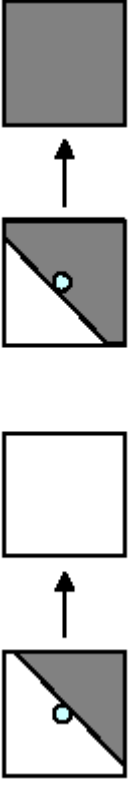
Octree

- Divide up space and record what objects are in each cell
- Trace ray through **voxel** array

Difference?



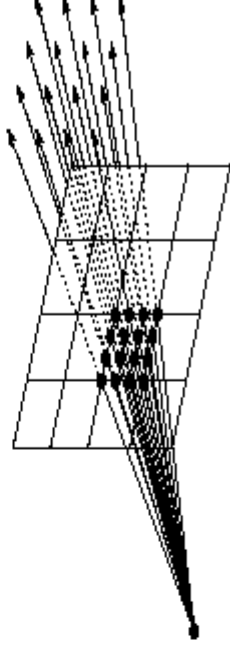
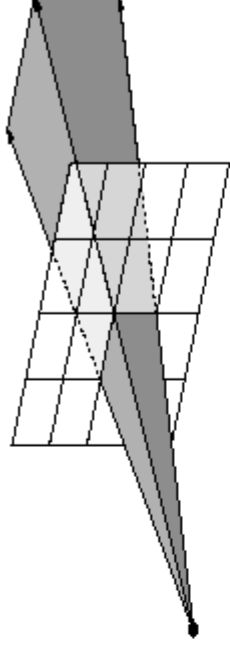
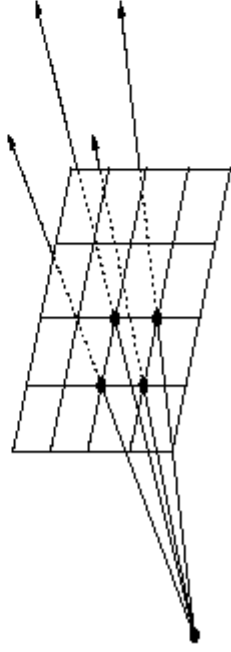
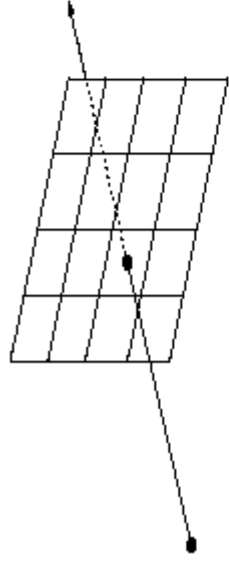
Antialiasing

- So far, we have traced one ray through each pixel in the final image. Is this an adequate description of the contents of the pixel?

- This quantization through inadequate sampling is a form of **aliasing**. Aliasing is visible as “jaggies” in the ray-traced image.
- We really need to color the pixel based on the *average* color of the square it defines.



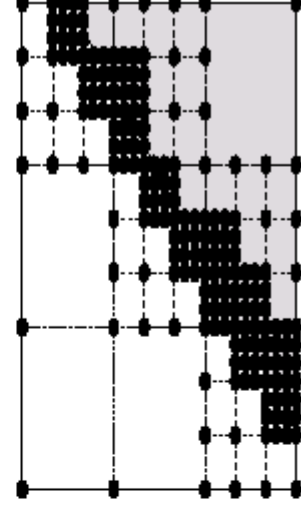
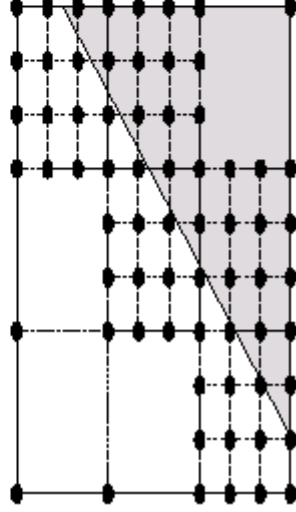
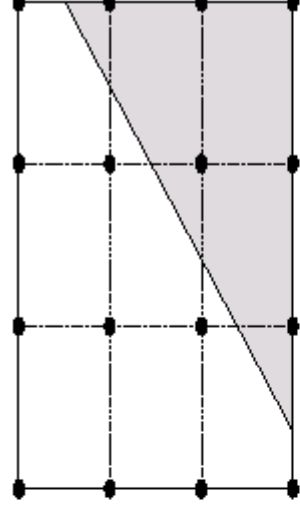
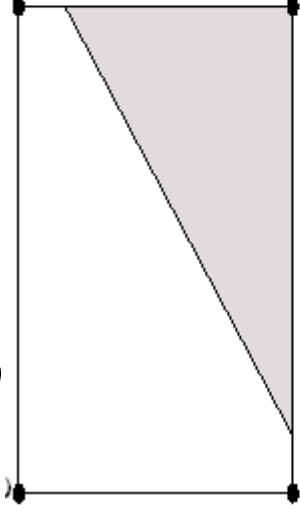
Supersampling

- We can approximate the average color of a pixel's area by firing multiple rays and averaging the result.



Adaptive Sampling

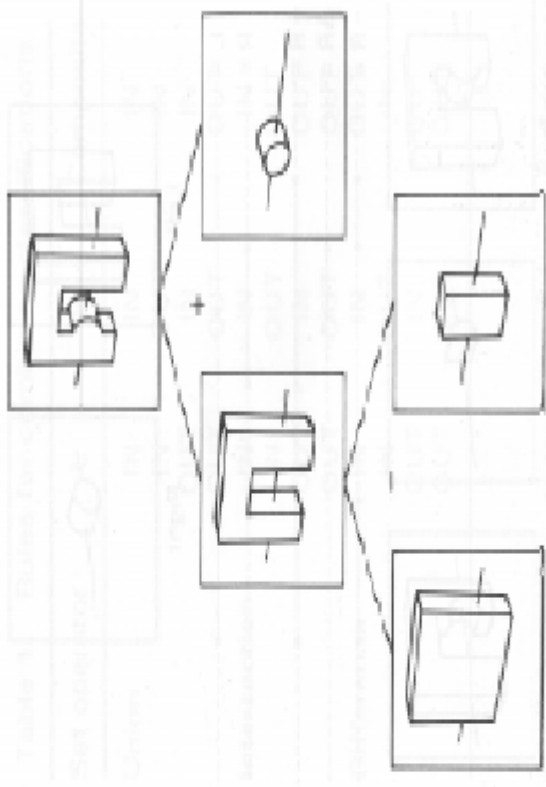
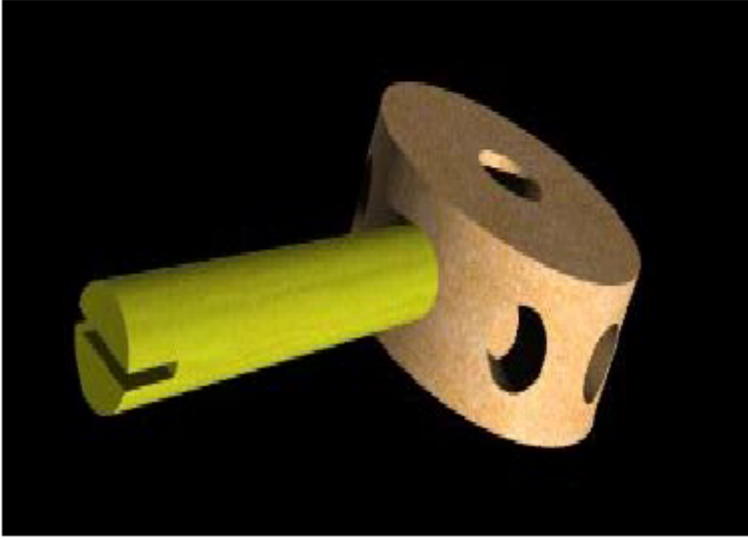
- Uniform supersampling can be wasteful if large parts of the pixel don't change much.
- So we can subdivide regions of the pixel's area only when the image changes in that area:



- How do we decide when to subdivide?

CSG

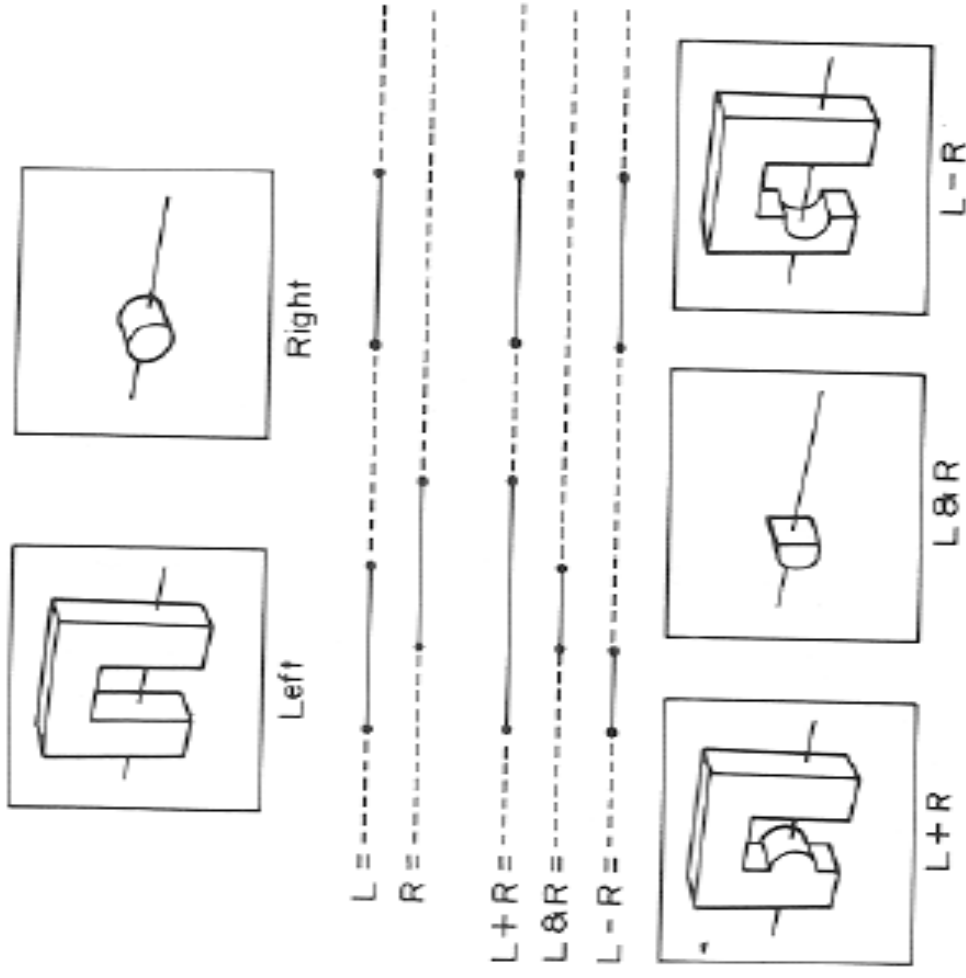
- CSG (constructive solid geometry) is an incredibly powerful way to create complex scenes from simple primitives.



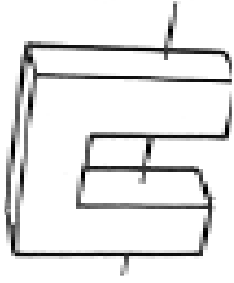
- CSG is a modeling technique; basically, we only need to modify ray-object intersection.

CSG Implementation

- CSG intersections can be analyzed using "Roth diagrams".
 - Maintain description of *all intersections* of ray with primitive
 - Functions to combine Roth diagrams under CSG operation
- An elegant and extremely slow system

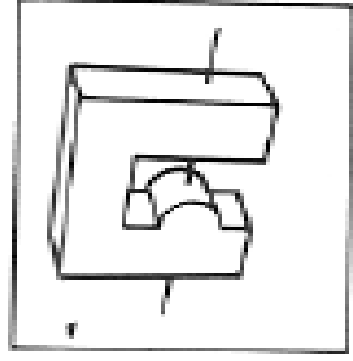


Consider raycasting one scanline on the left and right primitive respectively:

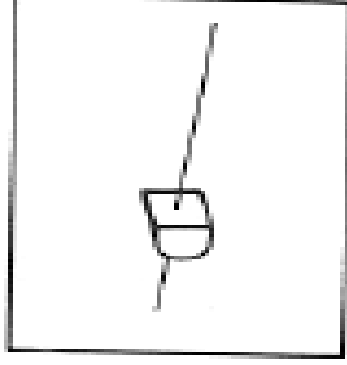


Left

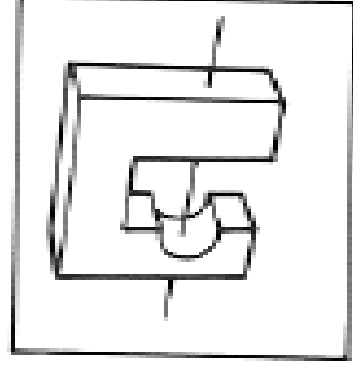
Right



$L + R$



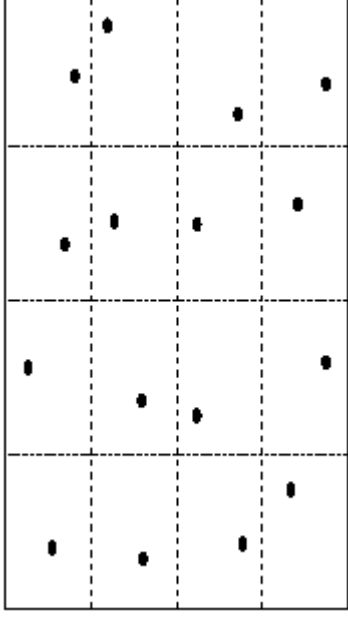
$L \& R$



$L - R$

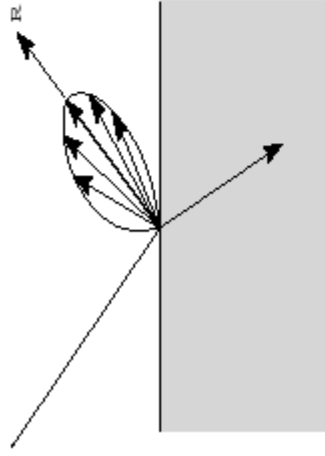
Distributed Ray Tracing

- Usually known as “distributed ray tracing”, but it has nothing to do with distributed computing
- General idea: instead of firing one ray, fire multiple rays in a jittered grid

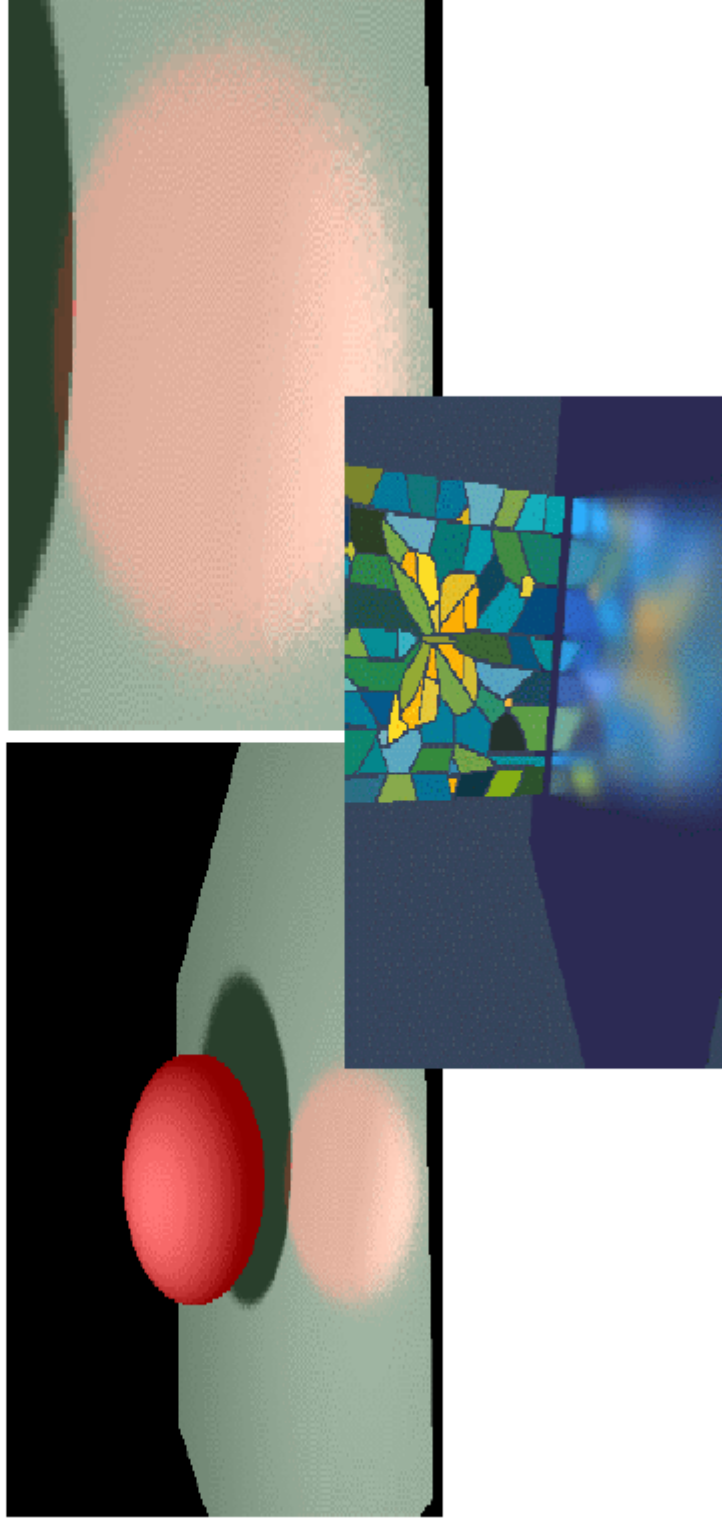


- Distributing over different dimensions gives different effects
- Example: what if we distribute rays over pixel area?
 - Supersampling a pixel (antialiasing!)

Distributed Reflections

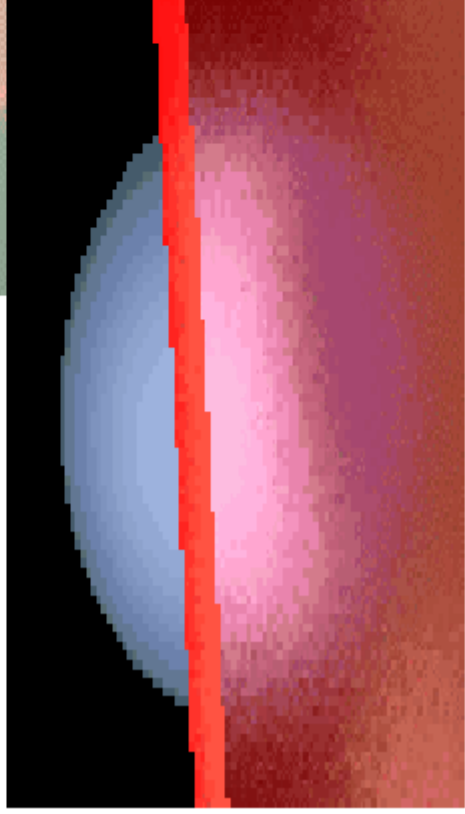
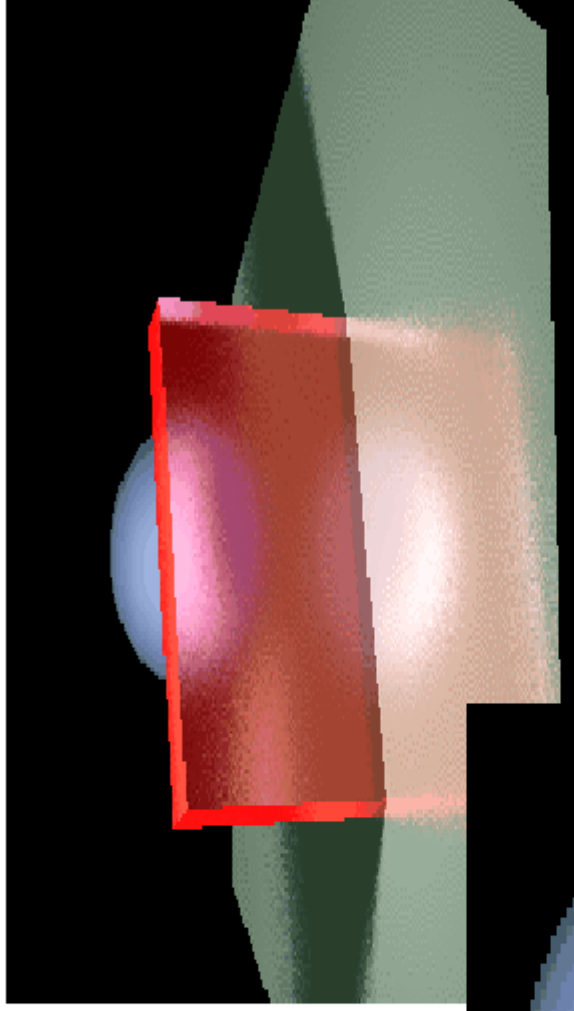


- Distributing rays over reflection gives:



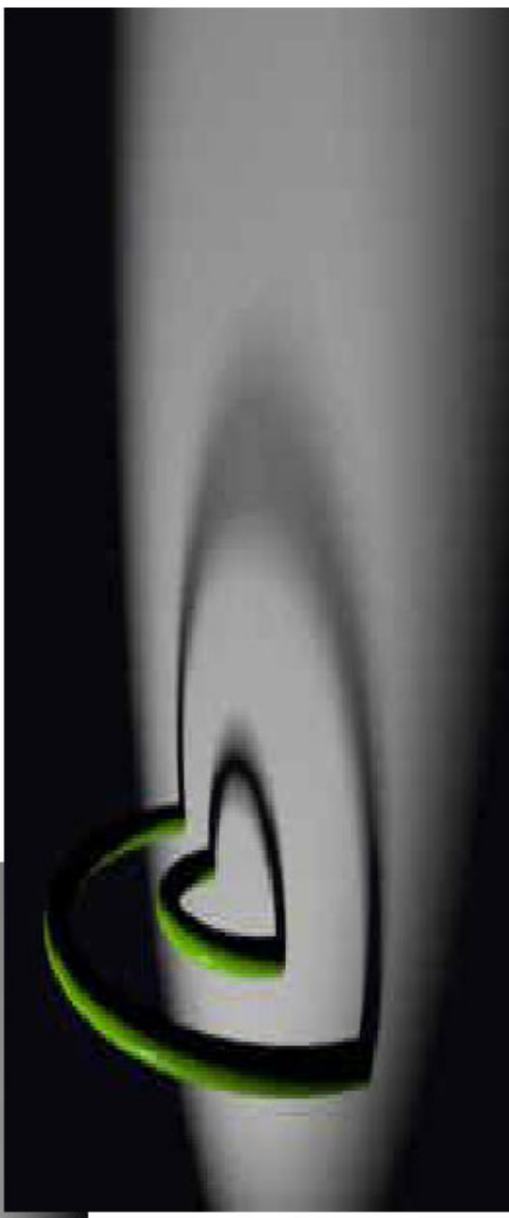
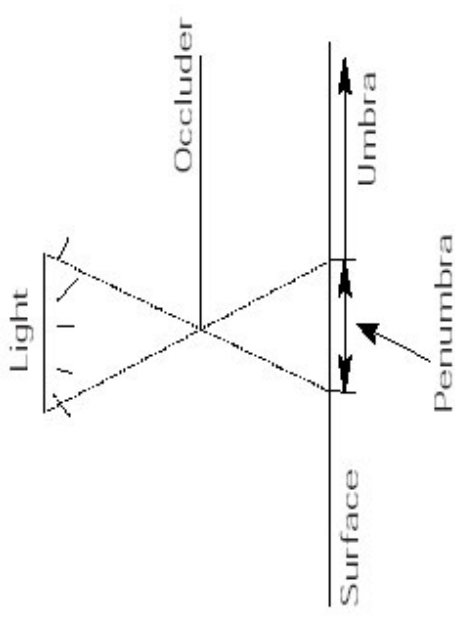
Distributing Refractions

- Distributing rays over transmission direction gives:



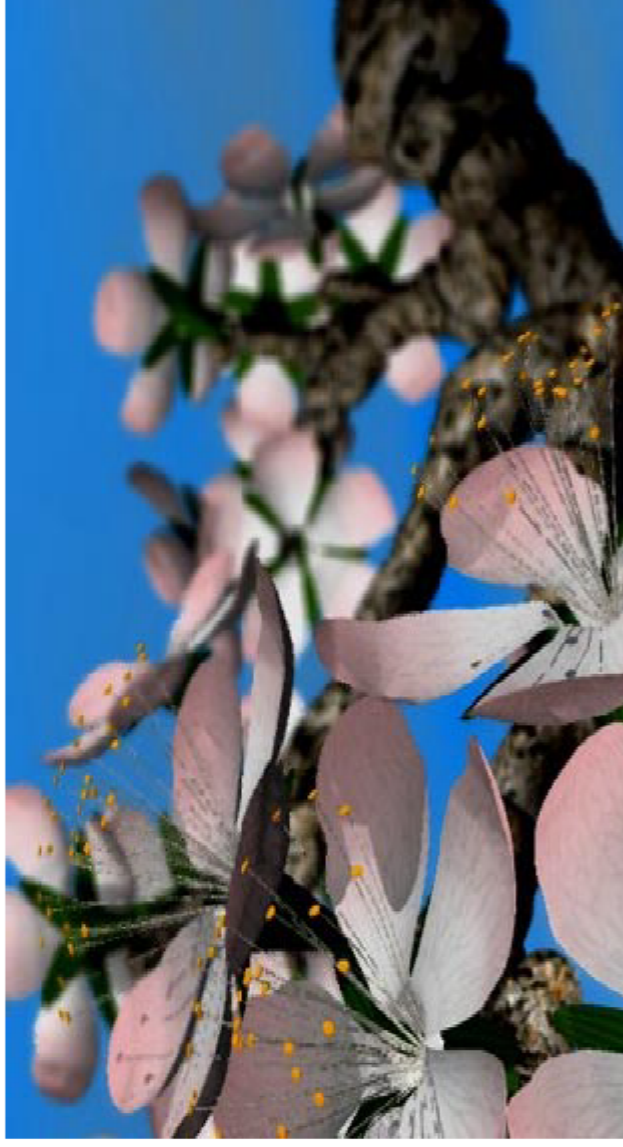
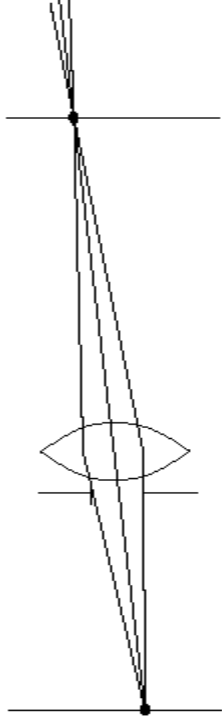
Distributing Over Light Area

- Distributing rays over light area gives:



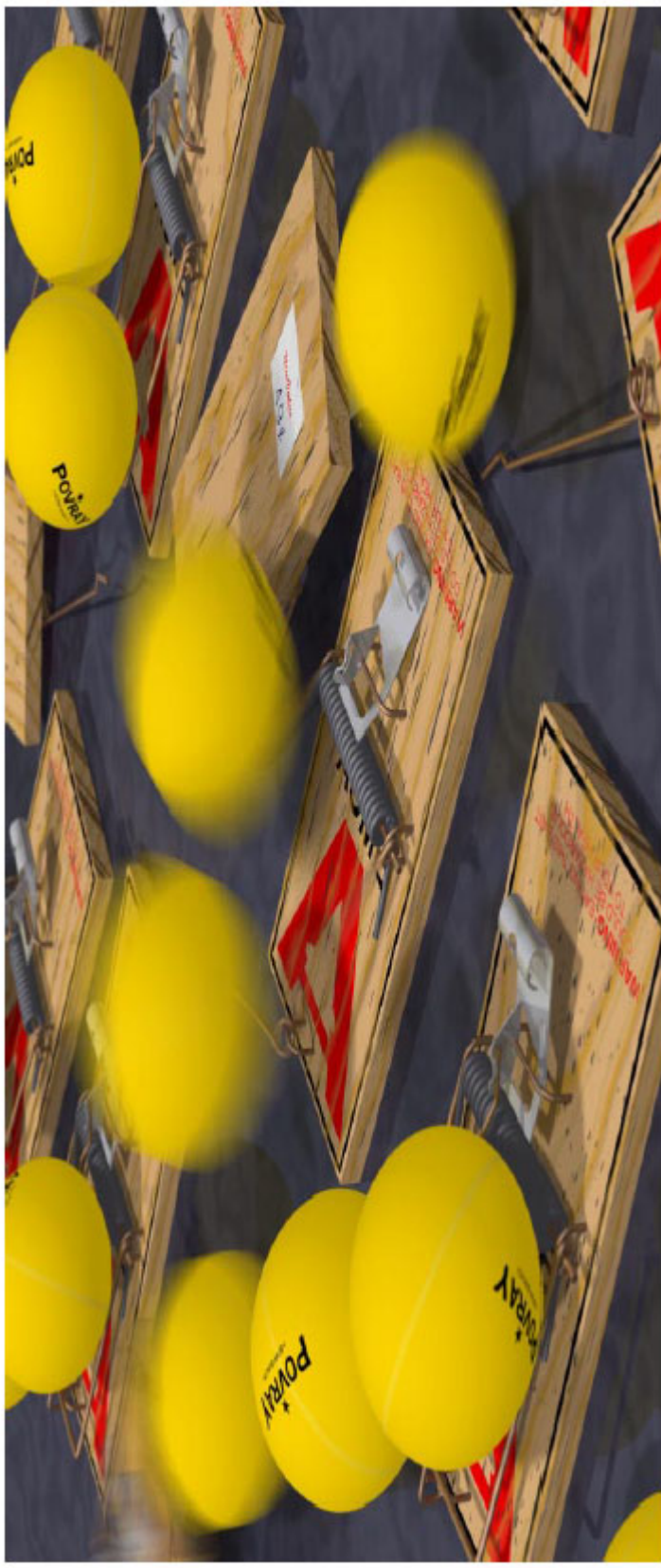
Distributing Over Aperture

- We can fake distribution through a lens by choosing a point on a finite aperture and tracing through the “infocus point”.



Distributing Over Time

- We can endow models with velocity vectors and distribute rays over *time*. This gives **motion blur**:



Summary

- Understanding of the idea and implementation strategies for:
- Ray tracing acceleration
 - Hierarchical bounding volumes
 - Spatial subdivision
- Antialiasing
 - Supersampling
 - Adaptive sampling
- CSG
- Distributed ray tracing
 - Antialiasing
 - Glossy reflection
 - Translucency
 - Soft shadows
 - Depth-of-field (out of focus)
 - Motion blur