CS451
Ray Tracing

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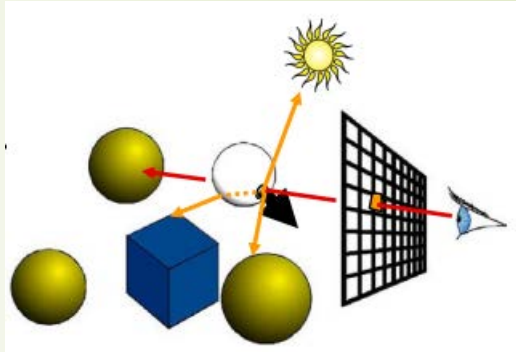
Based on notes from http://stellar.mit.edu/

Review: Intersections

- Ray-Sphere
  - Quadratic: $ax^2 + bx + c = 0$
  - Solution: $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

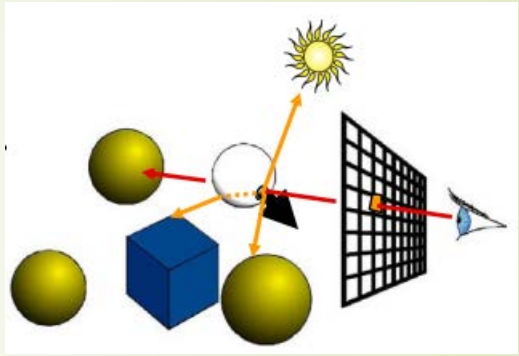
Ray Tracing

- Intersect all objects
- color = ambient term
- For every light
  - cast shadow ray
  - color += local shading term
- If mirror
  - color += color_reflection * trace reflected ray
- If transparent
  - color += color_transparent * trace transmitted ray

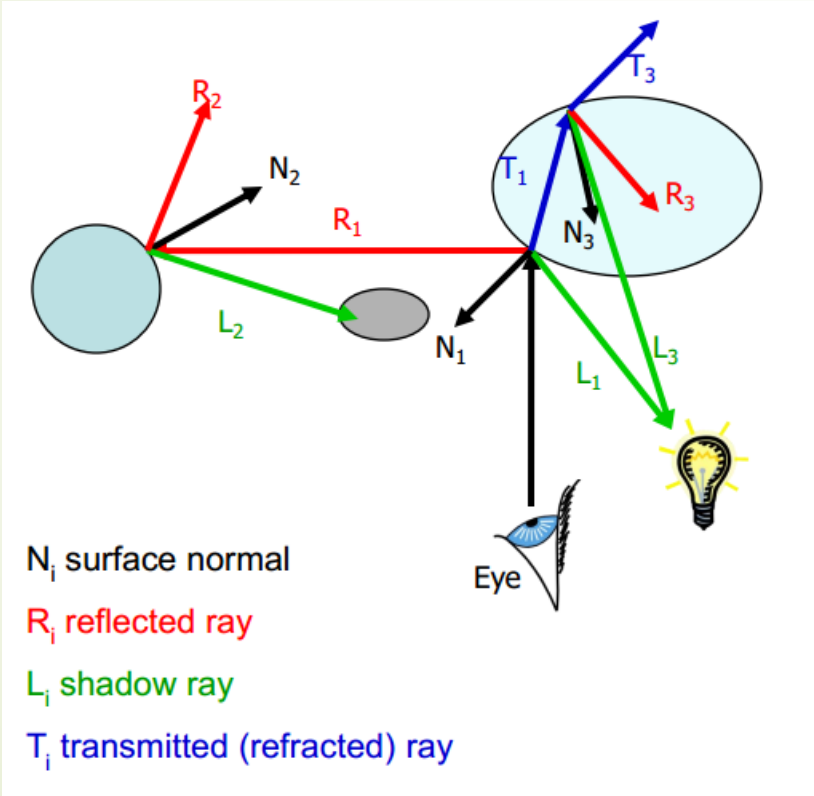


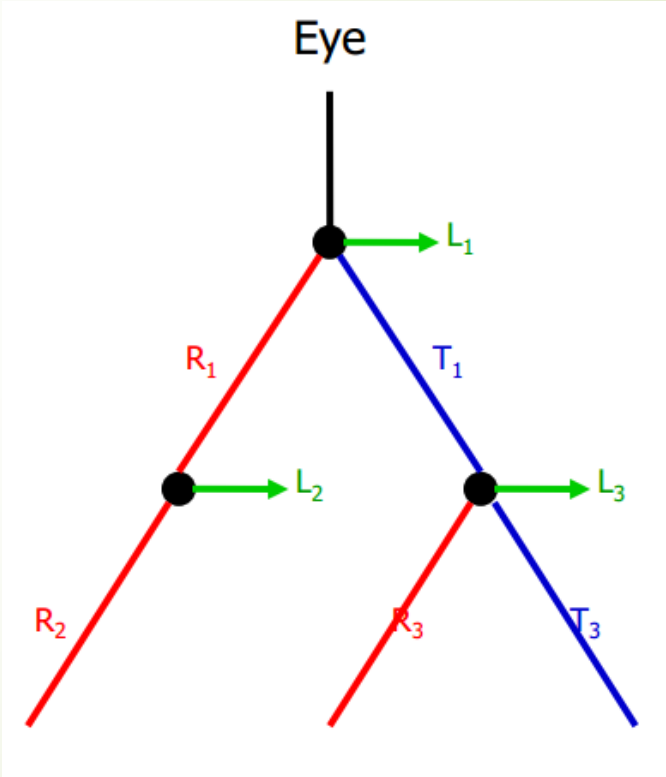
Ray Tracing

- Stopping Criteria (depth, engery, etc)
- Intersect all objects
- color = ambient term
- For every light
  - cast shadow ray
  - color += local shading term
- If mirror
  - color += color_reflection * trace reflected ray
- If transparent
  - color += color_transparent * trace transmitted ray



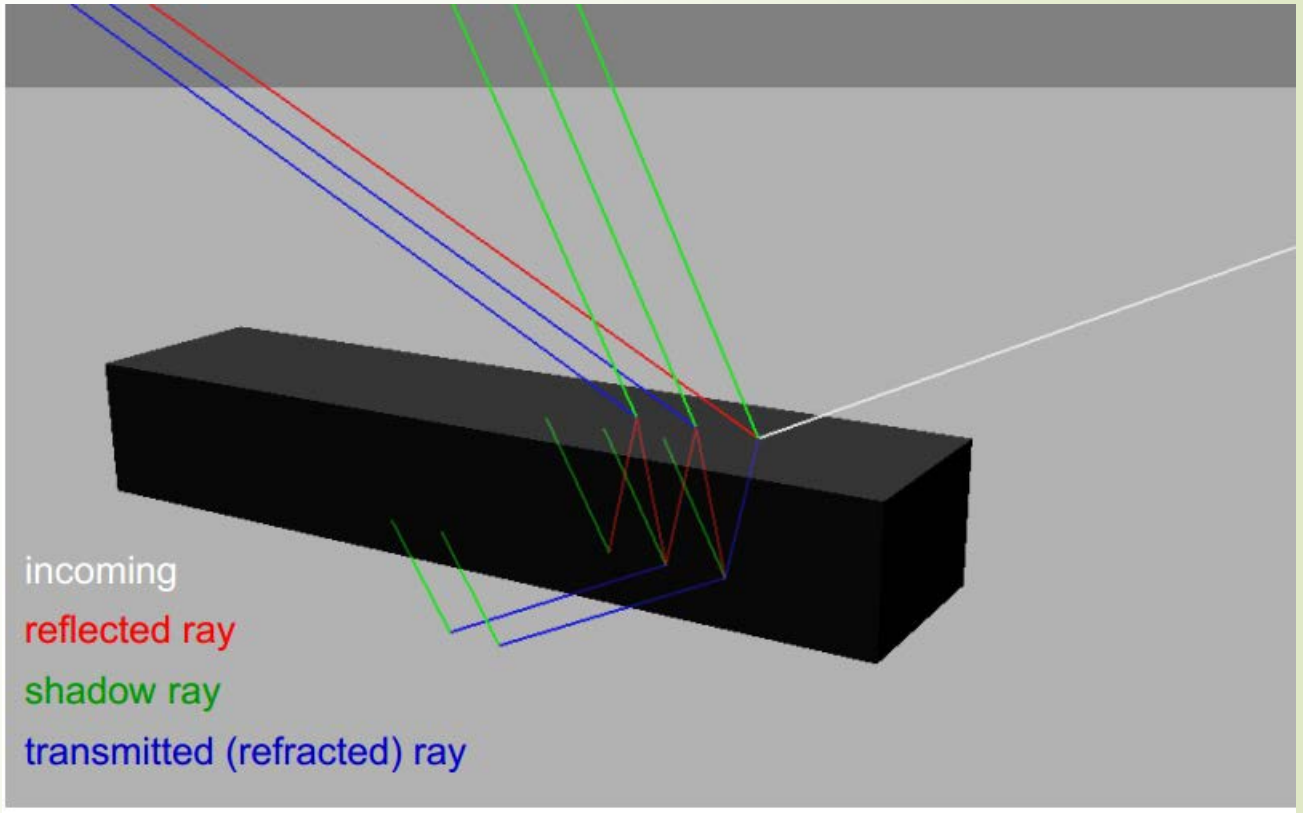
Ray Tree


R2
N2
R1
T3
T1
R3
N3
L2
N1
L3
L1
Eye
Ni surface normal
Ri reflected ray
Li shadow ray
Ti transmitted (refracted) ray


Eye
L1
R1
T1
L2
L3
R2
R3
T3

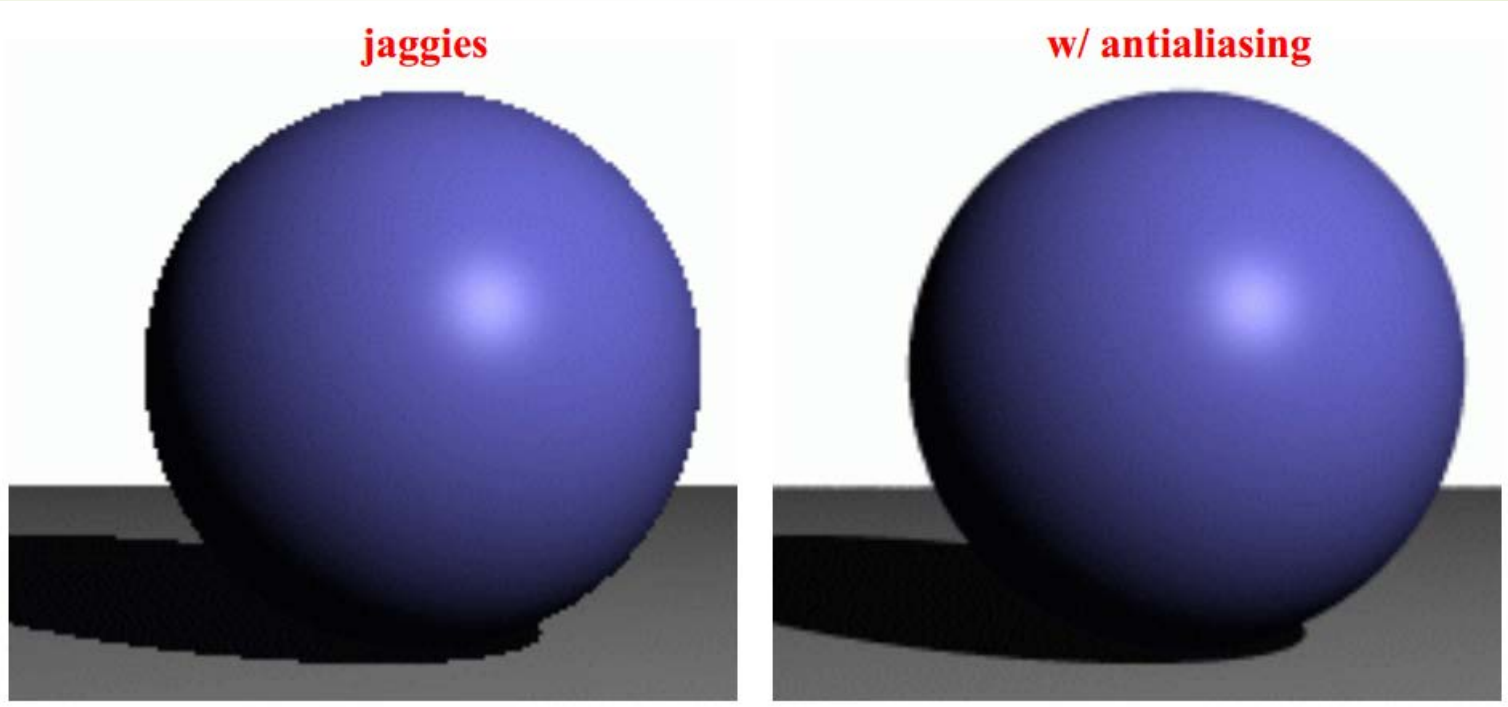
Ray Tree

- Visualizing the ray tree



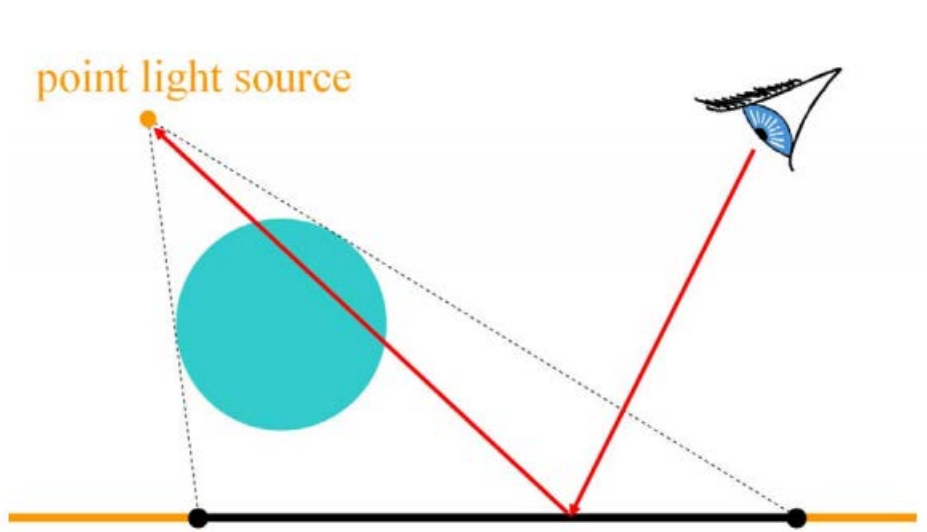
Antialiasing

- Supersampling – create many random rays per pixel

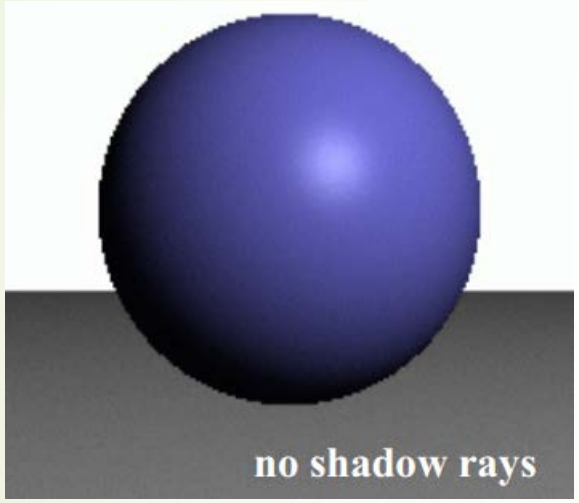


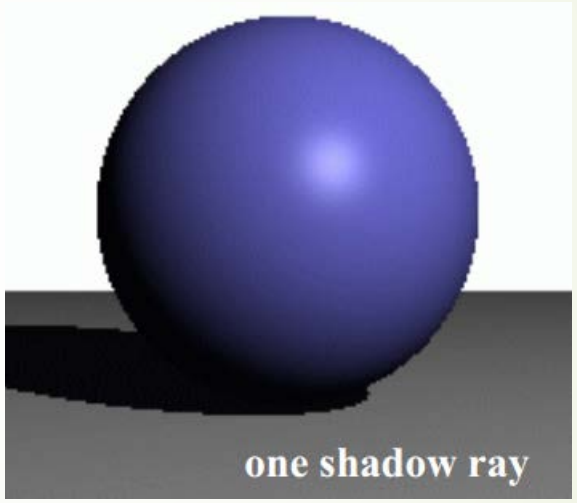
Shadow

- Shadow ray (between the point and the light)



Shadow





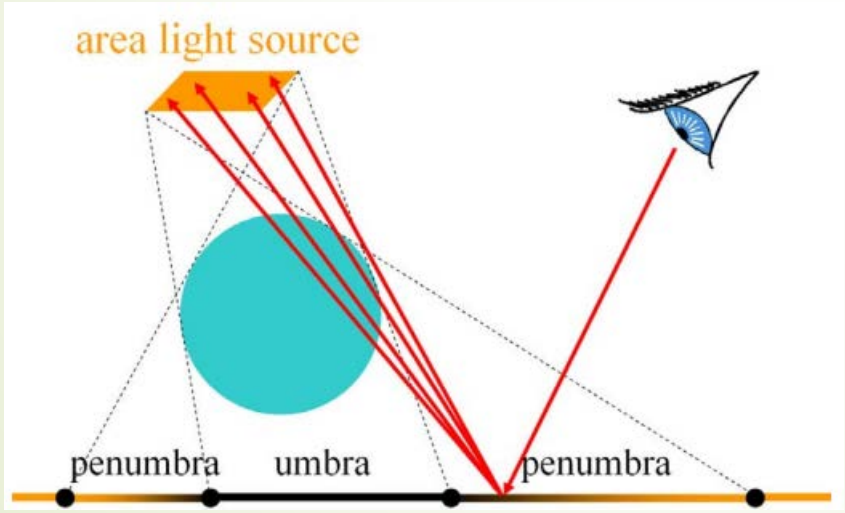
Soft Shadow

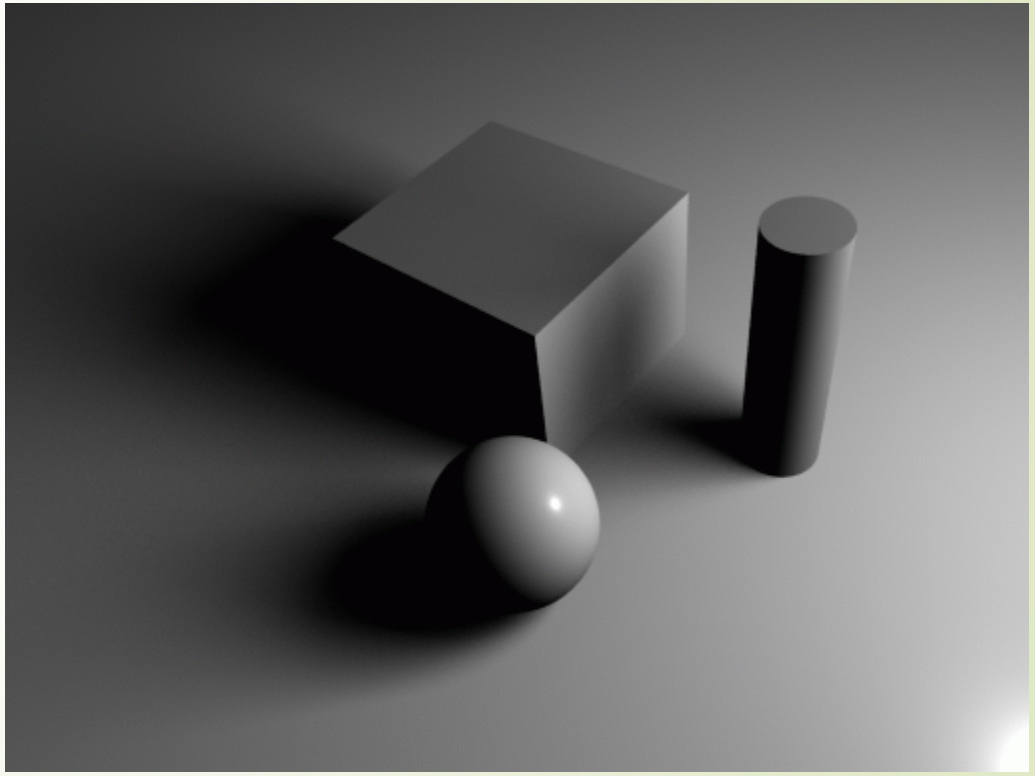
- In real world, most shadows have soft boundary
  - Due to the types, numbers, distances of light

http://www.pa.uky.edu/~sciworks/light/preview/bulb2.htm

Soft Shadow

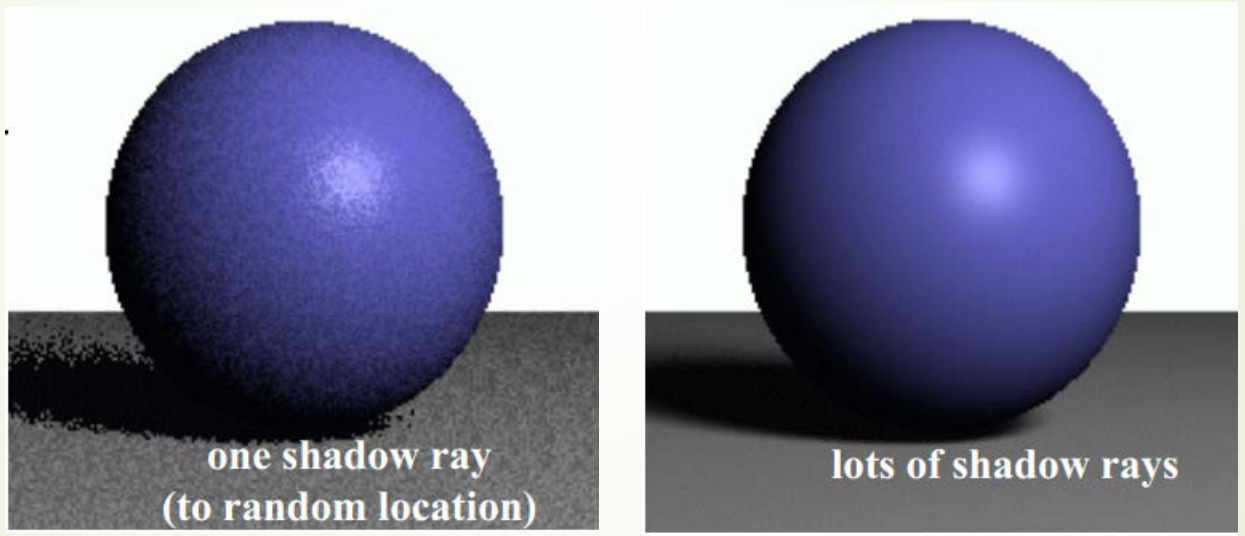
- Area light and super sampling





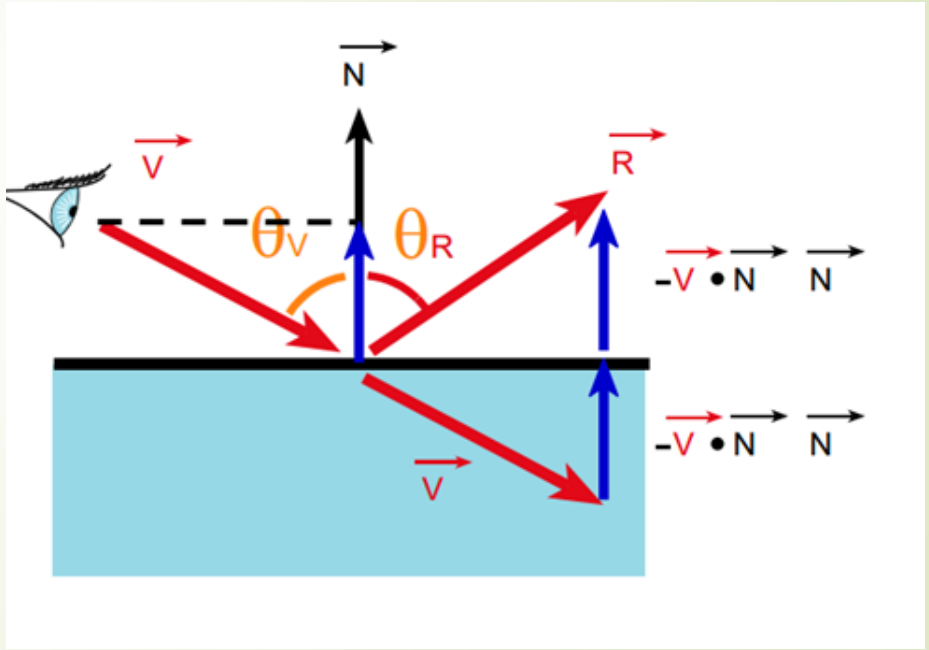
http://renderman.pixar.com/resources/current/rps/softShadows.html

Soft Shadow



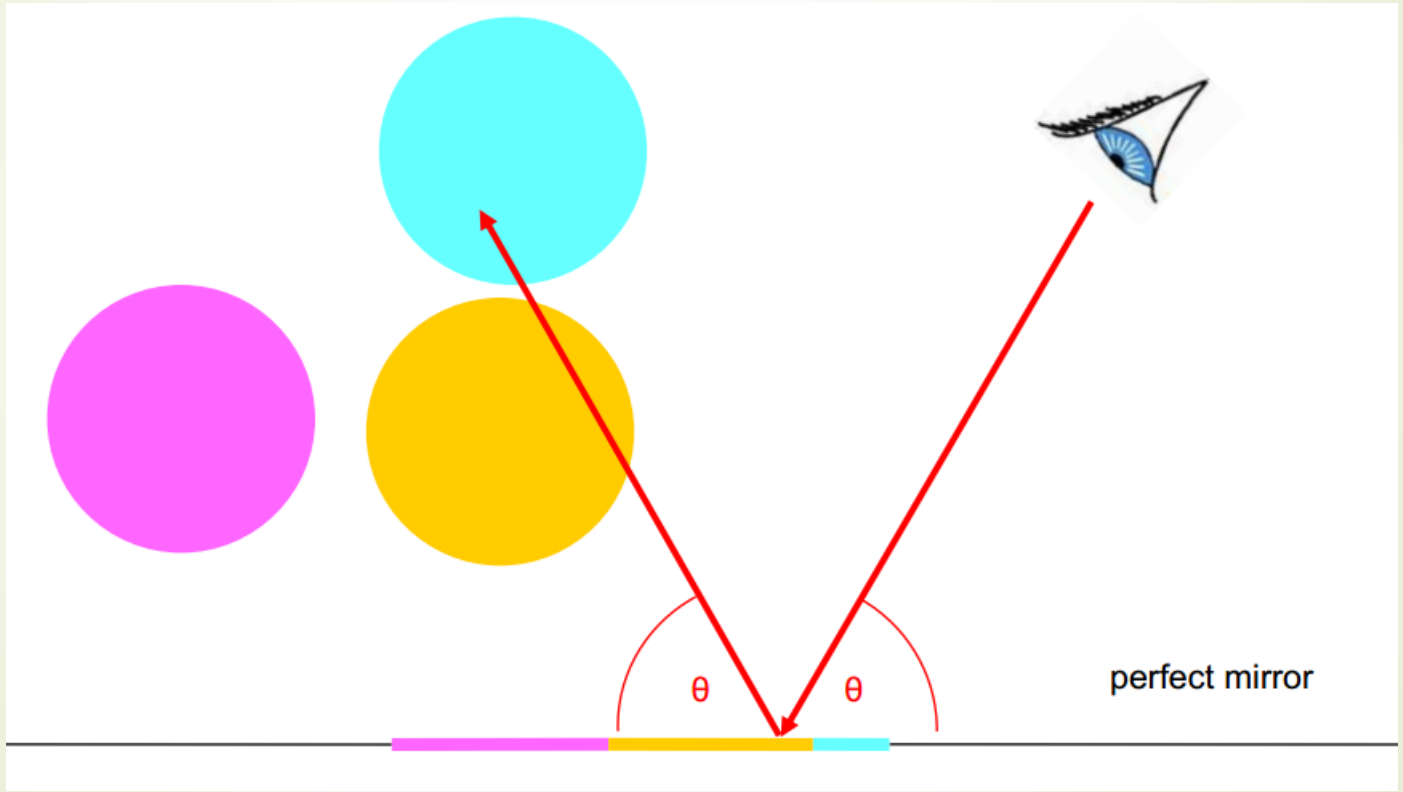
Reflection

- Cast ray symmetric with respect to the normal
  - $R = V - 2(V \cdot N)N$
- Amount of Reflection
  - Multiply by reflection coefficient (color)



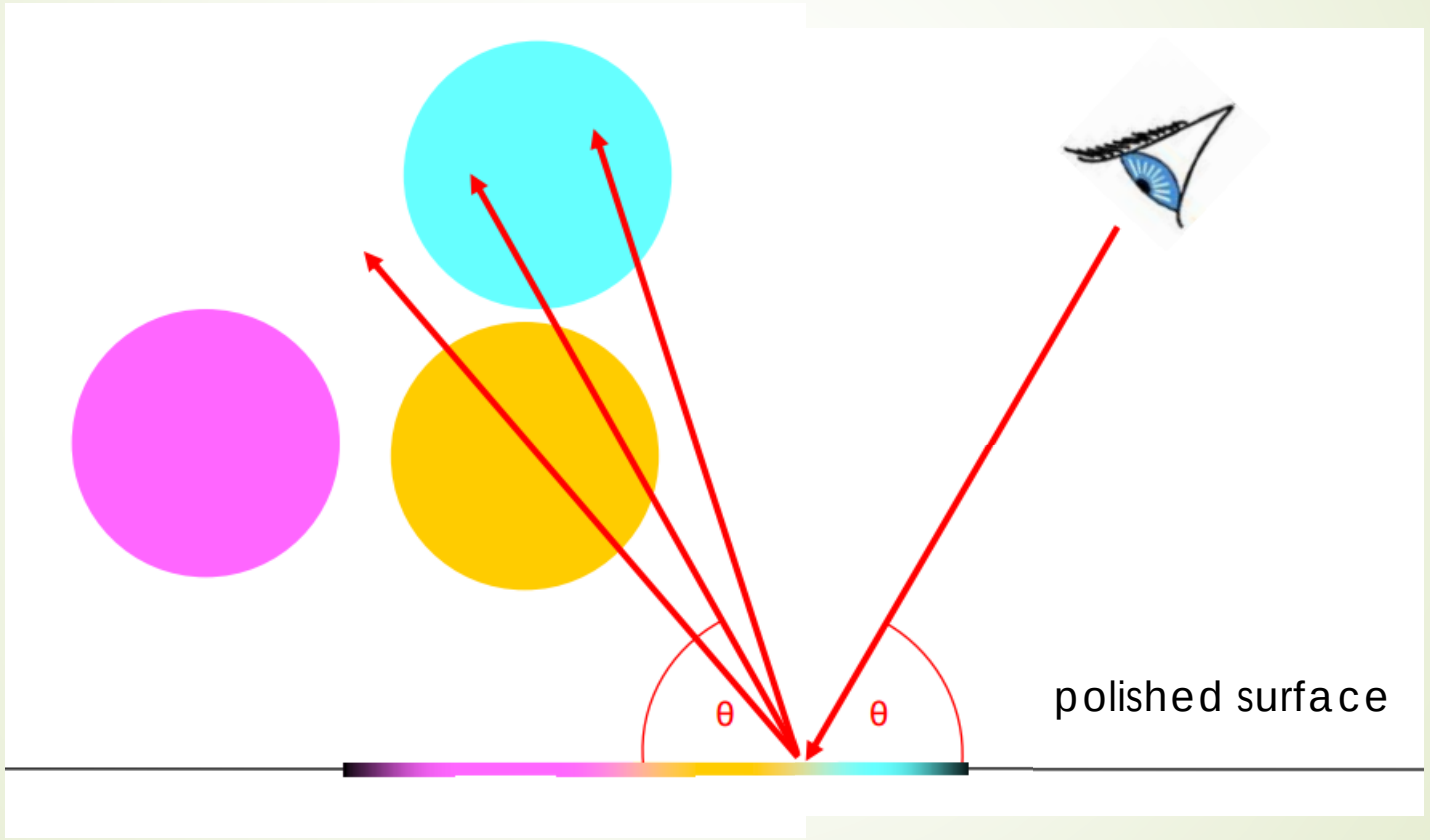
Reflection

A single reflection ray



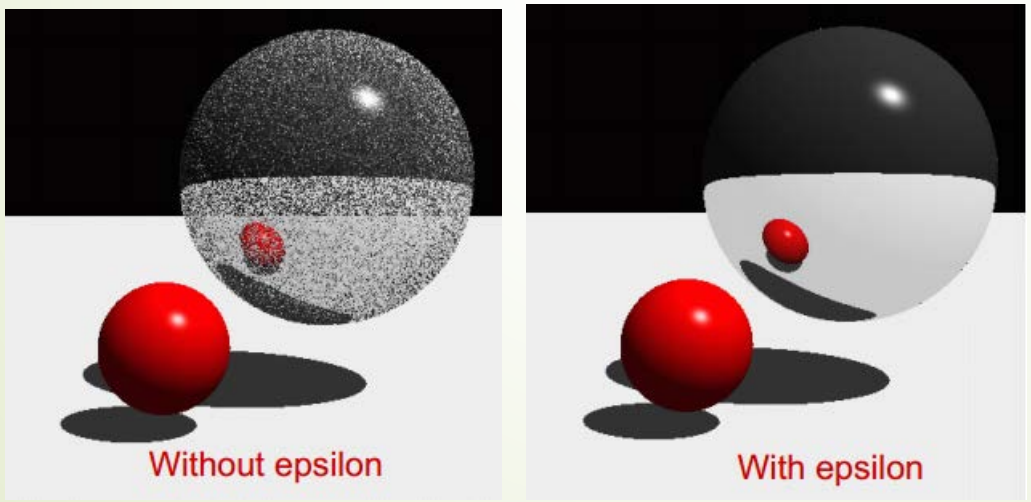
Reflection

Multiple reflection rays



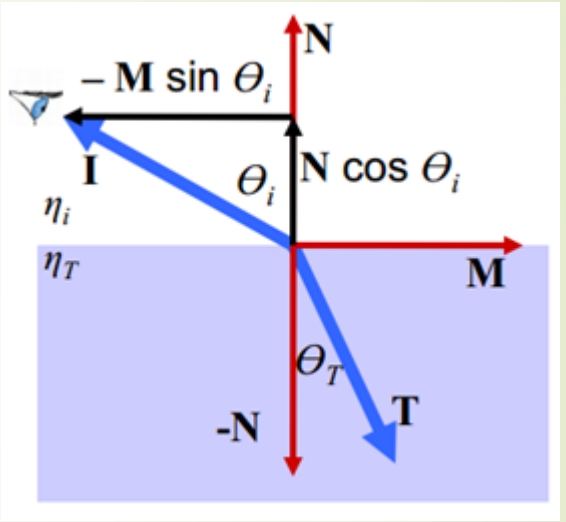
Reflection

- Cast ray symmetric with respect to the normal
- Multiply by reflection coefficient (color)
- add epsilon to the ray so the origin of the ray is a bit off the surface
  - Offset the ray in the normal direction of the surface



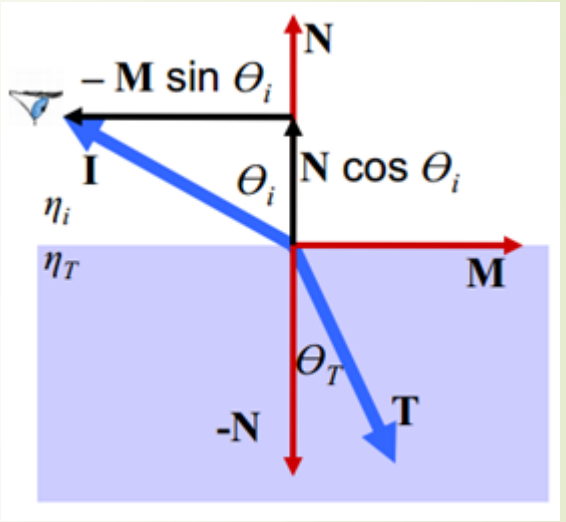
Refraction

- Cast ray in refracted direction
  - Relative index of refraction
    - $\frac{\sin\theta_T}{\sin\theta_i} = \frac{n_i}{n_T} = n_r$
- Amount of Refraction
  - Multiply by transparency coefficient (color)



Refraction

- Cast ray in refracted direction
  - $M = (N \cos\theta_i - I) / \sin\theta_i$
  - $T = -N\cos\theta_T + M\sin\theta_T$
  - $T = [\, n_r(N \cdot I) - \sqrt{1 - n_r^2(1 - (N \cdot I)^2)}\,]\, N - n_r I$
    - Total internal reflection if $(1 - n_r^2(1 - (N \cdot I)^2) < 0$
  - $\dfrac{\sin\theta_T}{\sin\theta_i} = \dfrac{n_i}{n_T} = n_r$



Refraction

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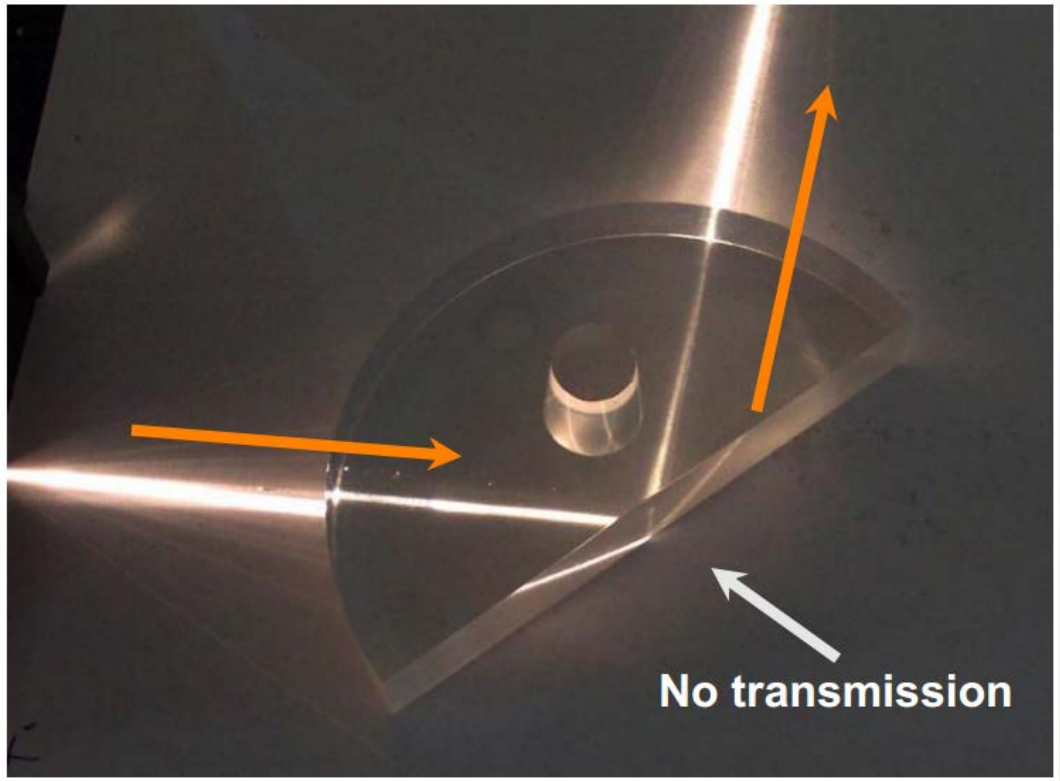
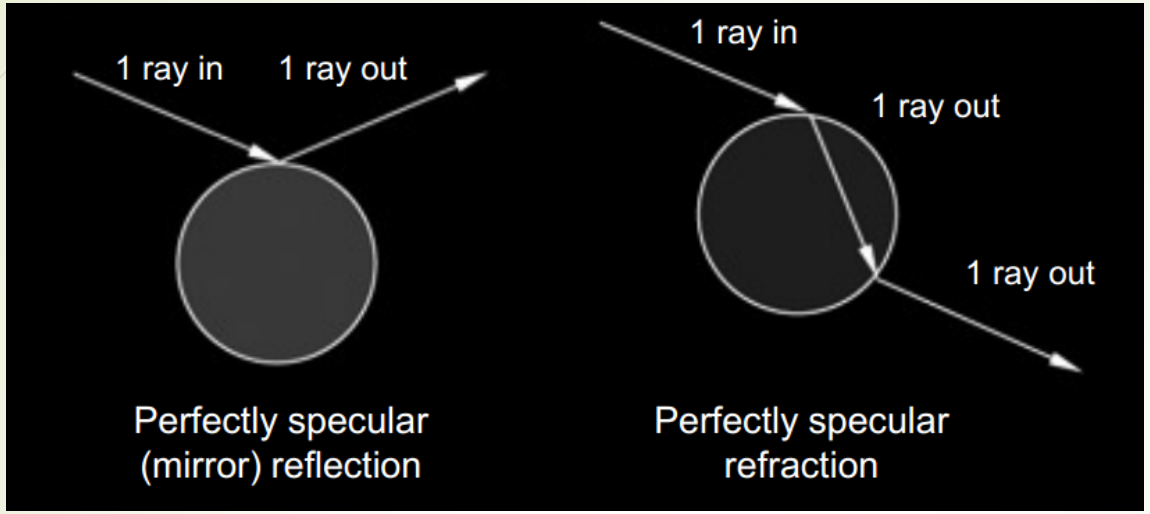
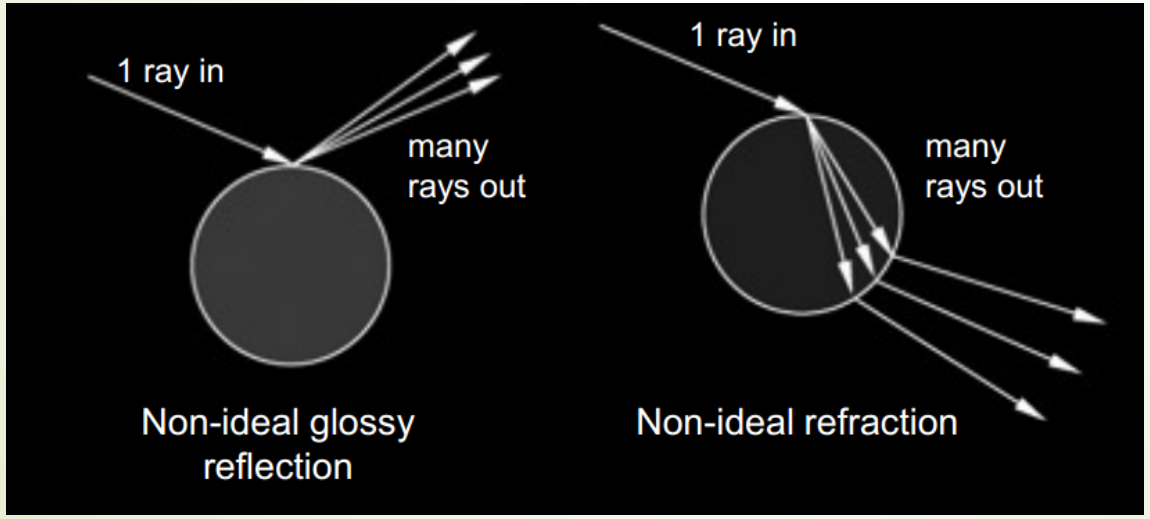


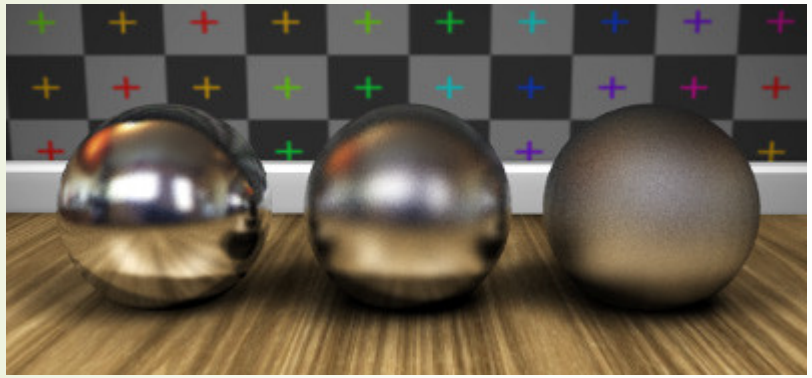
Refraction with Many Rays



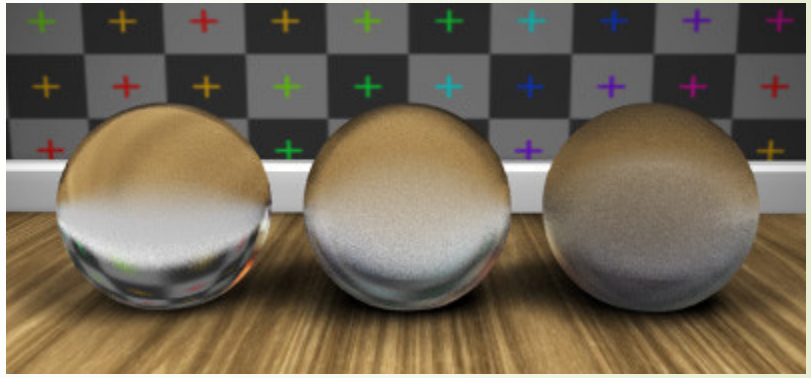


from blender.org

Refraction with Many Rays



Reflecting spheres with glossiness of 0.9, 0.8, and 0.6

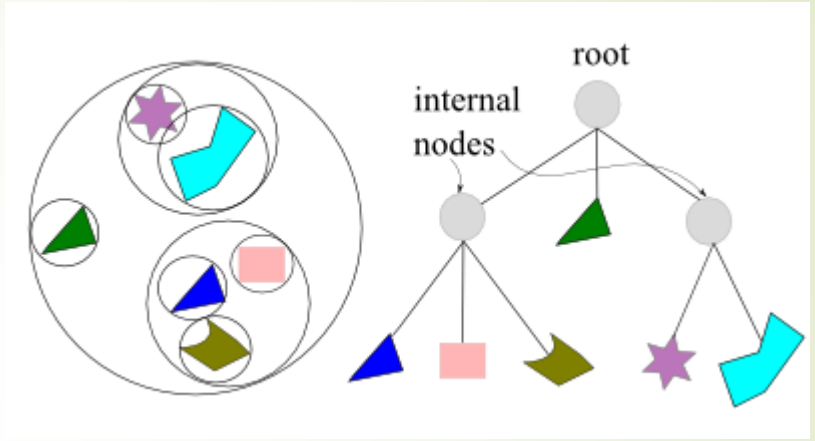


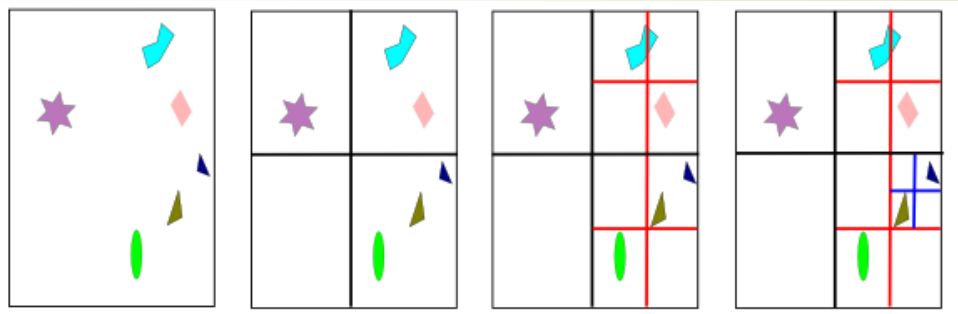
Refracting spheres with glossiness of 0.9, 0.8, and 0.6

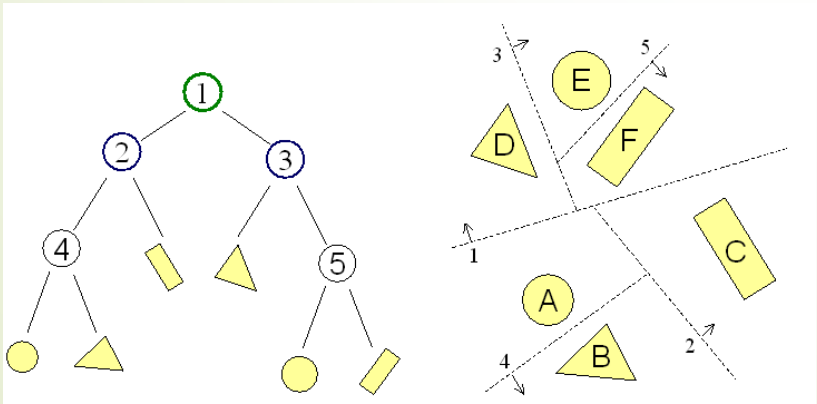
from blender.org

Data Structure for Ray tracing

- Bounding volume hierarchy
  - Bounding spheres, boxes, etc
  - Quadtree/Octree
  - Binary space partition tree







http://www.bogotobogo.com/Games/spatialdatastructure.php and http://www.cs.princeton.edu/courses/archive/fall00/cs426/lectures/raycast2/sld018.htm

Questions?

- What we learned today
  - Ray tracing framework
  - Reflect
  - Refraction
  - Soft shadow, reflection, refraction